Journal of Business and Social Science Review
Issue: Vol. 1; No.5May2020 pp.18-28
ISSN 2690-0866(Print) 2690-0874 (Online)
Website: www.jbssrnet.com
E-mail: editor@jbssrnet.com

Energy Poverty during the Era of Economic Crisis in the Island of Crete, Greece

John Vourdoubas
Mediterranean Agronomic Institute of Chania
73100, Chania, Crete, Greece
Tel: +30-28210-35020, Fax: +30-28210-35001
E-mail: vourdoubas@chania.teicrete.gr

George Plokamakis
DEDDIE, 25 Sof. Venizelou str., Mournies, 73300
Crete, Greece
E-mail: g.plokamakis@deddie.gr

Antiope Gigandidou
DEDDIE, Kastorias str., Katsabas, 71307
Heraklion, Greece
E-mail: a.gigantidou@deddie.gr

Abstract

The recent economic crisis has increased the number of households in EU countries who are unable to provide the required energy in their homes. Greece has experienced a severe economic crisis during this period with a sharp decrease in the GDP resulting in an increased number of households living under energy poverty. The purpose of the current work is to assess the energy poverty in the island of Crete, Greece during the period 2007-2018. And additionally to review the governmental policies for tackling energy poverty as well as the presentation of the appropriate renewable energy technologies which could be used in residential buildings in Crete in order to reduce the energy deprivation of households. The work includes an analysis of electricity and heating oil consumption in the island during this period and the comparison of their changes with the changes in the GDP of the country. Our findings indicated that although electricity consumption changes were small during this period in Crete, a large decrease in heating oil consumption has been recorded. However the total energy of both electricity and heating oil consumed in Crete has been reduced in consistency with the reduction of the Greek GDP, indicating that the number of energy-poor households has been increased. Governmental policies fighting energy poverty are consistent with the adopted policies in other EU countries. Our findings indicated that the increased use of renewable energies available in Crete in residential buildings could assist households to reduce their energy expenses, enabling them to provide adequate energy in their homes.

Keywords: Crete-Greece; economic crisis; electricity; energy poverty; GDP; heating oil;

1. Introduction

Energy poverty consists of an important problem affecting the health and quality of life of millions of households in Europe and worldwide. It is related with the economic difficulty and inability of households to provide the required energy in their homes. The recent economic crisis during 2007-2008 has hurt Greece, sharply reducing the national Gross Domestic Product (GDP) and the annual income of the majority of the population. This has resulted in the increase of energy poverty in the country while the low income households were more vulnerable to it. Regional studies in Greece regarding energy poverty are limited.

However mapping the level and the characteristics of energy poverty in Greek territories during the era of economic crisis is important while it will assist in the development of appropriate regional policies, tailor-made for each territory, to fight it. The population of Crete is estimated at 634,930 inhabitants (2019) while the annual GDP per capita is almost the same with the country's average. Tourism is the dominant economic activity in the island contributing around 47% in the regional GDP. Agriculture and industry have a minor contribution to Cretan GDP which is dominated by the service sector. The climate in Crete is mild Mediterranean type with an average annual air temperature of approximately at 20^{o}C. There is a broad consensus among researchers that energy deprivation of households is a multi-faced problem needing a multidimensional approach. In order to assess the economic poverty in the island of Crete, Greece, during 2007-2018, a literature survey was initially implemented. The energy consumption in residential buildings has been reviewed followed by the estimation of the Greek GDP, the electricity consumption, as well as the heating oil consumption in the island during this period. A presentation of the governmental policies for energy poverty mitigation follows together with the presentation of the cost-effective renewable energy technologies which could be used in residential buildings in Crete to tackle energy poverty. The last part of the work includes the discussion of the findings together with conclusions drawn and proposals for further research.

1.1 Energy poverty

Herrero, 2017 has reviewed the methods and the indicators used for assessing energy poverty. The author mentioned that a single indicator for measuring energy poverty has various limitations. He stated that a multiple indicator approach represents better the energy poverty status. **Middlemiss et al, 2015** have studied fuel poverty in the UK. The authors mentioned that during the last decade, the fuel poverty gap has increased in this country. They explored the energy vulnerability of energy-poor households, identifying six parameters affecting it including: quality of dwelling's fabric, energy cost and supply, stability of household income, tenancy relations, social relations within the household and outside, and finally ill health. They found that these households had limited possibilities to reduce their own vulnerability. **Maxim et al, 2016** have reported on a new indicator for measuring energy poverty across EU countries. The authors mentioned that this new indicator, the compound energy poverty indicator, is composed from five parameters including: a) poor dwelling quality, b) arrears to utilities, c) self-assessed inability to maintain the home adequately warm, d) share of a population living in a dwelling not comfortably cool during summer time, and e) share of population considering their dwellings as too dark. The **European Development Bank, 2019** has studied how energy efficiency and use of renewables could combat energy poverty in Europe. The report mentioned that renewable energies would be a crucial driver combating energy poverty when accompanied by household energy efficiency improvements. It also stated that, in 2016, 23% of Greek people were unable to keep their home warm while in the bottom 20% of income distribution, it was exceeding 50%. **Thomson et al, 2018** have reported on energy poverty in the EU. The authors mentioned that energy poverty should be measured using multiple indicators in tandem as it is a complex multi-dimensional issue. They also stated that, in 2016, 44.5 mil people were unable to keep their home warm while 41.5 mil people had arrears in their utility bills. **Kyprianou et al, 2019** have studied the energy poverty policies in five EU countries. The authors investigated the policies and measures adopted in Cyprus, Spain, Portugal, Bulgaria and Lithuania for fighting energy poverty. Through comparative analysis, the authors identified the strengths and weaknesses of the national strategies. **Bouzarovski et al, 2015** have reported on domestic energy deprivation. The authors argued that the concept and the notions of energy and fuel poverty are obsolete although they are recognized by policy makers. They proposed that policies should be focused in providing energy services, ensuring that vulnerable households would cover their energy needs.

1.2 Energy poverty in Greece

Metaxa, 2018 has proposed a holistic approach for tackling energy poverty. The author mentioned that energy poverty in Greece was close to 36% in 2015. She also stated that energy poverty is a multidimensional phenomenon affected by the low income of households, high energy prices and poor building efficiency while its tackling requires a holistic policy. **Atsalis et al, 2016** have analyzed the energy poverty in Greece. The authors mentioned that around 20-25% of Greek households were in fuel poverty in 2013 while with subjective measures this percentage reaches 29.5%, twice as in 2010. They suggested the promotion of a development program by the government regarding energy savings in residential buildings.

Parada et al, 2016 have studied the advantages of underground constructions for fighting energy poverty. The authors studied the energy behavior of dwellings in different climatic zones in Greece. Their findings indicated that an underground dwelling can meet its energy needs more easily than a similar aboveground building. **Parada et al, 2016** have measured energy poverty in Greece. The authors mentioned that 58% of the Greek households are energy poor while 75% of them have reduced various essentials in favor of energy needs. They also stated that in climatic zone A 54% of the households are energy poor while the Greek energy policy has failed to tackle efficiently energy poverty in the country. **Katsoulakos, 2011** has studied the combating of energy poverty in mountainous areas in Greece with reference to the area in Metsovo located in Northern-West Greece. The author stated that Greek households in mountainous areas are vulnerable to energy poverty since their income is low. He also mentioned that using cost-effective energy-saving techniques in their dwellings combined with the utilization of locally produced solid biomass households could combat energy poverty. **Sardianou, 2008** has estimated the space heating determinants of Greek households. The author mentioned that the significant factors influencing residential demand for space heating included age, number of persons in the household, household ownership and size. Less important factors included existence and age of children, type of dwelling and thermal quality of the building. **Papadopoulos et al, 2008** have evaluated the three most popular heating systems operated in Greek mixed-use buildings including a central oil-fired boiler, a unitary gas-fired boiler and unitary heat pumps. The authors concluded that natural gas and autonomous systems were by far the cheapest and cleanest solution. They also stated that electric heat pumps could be the optimum solution in heating Greek buildings. **Santamouris et al, 2007** have studied the relation between energy and the social characteristics of the residential sector in Greece. The authors collected various data from 1,100 households, divided in seven income groups, located in Athens, Greece. Their findings indicated that low income households are more likely to live in old buildings with poor conditions while they pay more for their heating and electricity. They also mentioned that energy poverty was at 21.1% while in the low income group it was at 60%. **Santamouris et al, 2013** have investigated the relation of economic crisis and energy consumption in Greece. The authors collected data during 2010-2012 from 598 households. Their findings indicated that three fourths of the households belonging in the low income group lived in a smaller space, had half the income and consumed more specific energy compared to the high income group. They also mentioned that 2% of the high income households and 14% of the lower income households were below the fuel poverty threshold. **Dagoumas et al, 2014** have assessed the impact of the economic crisis on energy poverty in Greece during the period 2010-2012. The authors examined electricity consumption per capita as an appropriate indicator for energy poverty. Their findings indicated that electricity consumption was reduced by 3-9.5% while large cities were more affected than smaller towns, rural and remote areas. They also mentioned that there is a lag in the effect of economic crisis on the electricity consumption due to the fact that people require some time to respond in their new economic conditions. **Korovesi et al, 2017** have reported on energy poverty in Greece. The authors proposed various measures for the reduction of energy poverty in the country including: a) Changes in the current social policy tackling energy poverty, b) Education and training of households, c) Increase in energy efficiency in buildings, and d) Use of renewable energy resources in them. **A report on energy poverty in Greece has been published, 2019**. The report mentioned that Greece, Cyprus and Bulgaria are the three EU countries having the highest energy deprivation of households. In Greece 70% of the households were unable to keep the indoor temperature at satisfactory levels, 50.7% had arrears in utilities while 29.5% resided in low quality buildings. **Boemi et al, 2020** have studied the energy behavior and the energy poverty of households in Northern Greece. The authors implemented a case study collecting data from 384 households in Northern Greece. Their results indicated that energy poverty had affected a significant proportion of Greek households while 20% of them had arrears in their utilities. They also stated that energy poverty appeared more in urban areas. **Panagiotopoulos et al, 2015** have studied the "energy landscape" in Greece using geographical information systems in order to understand the spatial pattern of energy demand, consumption and cost. Their results indicated that, regarding Crete, the energy consumption for heating residential buildings per household did not exceed 16 MWh/year while the overall energy consumption did not exceed 23 MWh/year. The total annual cost per household did not exceed 4,000 €/year. The authors concluded that areas in northern Greece as well as mountainous areas require more energy per household resulting in higher annual energy costs. **Boemi et al, 2017** have studied the domestic energy deprivation in Greece. The authors investigated 762 households located in the regions of Western and Central Macedonia in Northern Greece. The research was implemented in the middle of the severe economic crisis in the country and the results indicated that the middle class was the most vulnerable to energy poverty. A report on the energy sector in Greece has been published by **IENE, 2019**.

The report mentioned that during the recent economic crisis the prices of electricity and heating oil have been substantially increased. Due to this fact many households are unable to heat and cool their homes adequately. It also stated that the heating cost for households with low income is higher than the cost of households with higher income due to the fact that low income families reside in lower quality buildings. **Vourdoubas, 2017** has presented a small residential building with net zero CO_2 emissions due to energy use located in Crete, Greece. The covered surface of the building was 65 m^2, its annual specific energy consumption was 180 KWh/m^2 while its annual CO_2 emissions were at 84.67 $kgCO_2/m^2$. The author stated that the residential building had zeroed its net total annual carbon emissions using solar thermal energy, solar-PV energy and solid biomass. **Vourdoubas, 2016** has studied the creation of net zero CO_2 emissions residential buildings due to energy use in the island of Crete, Greece. The author stated that the combined use solar thermal energy, solar-PV energy, solid biomass and high efficiency heat pumps could cover all the annual energy requirements of residential buildings in Crete zeroing their net carbon emissions. He also stated that the abovementioned technologies are mature, reliable and cost-effective. **Vatavali et al, 2018** have studied the energy poverty in Athens, Greece during the period of the recent economic crisis. The authors mentioned that during 2016 the majority of the Greek households (55.9%) were using oil or gas for heating their homes, 7.8% were using wood fuel and 9.9% were using heat pumps. They also mentioned that there were some areas in Athens where the buildings did not have any thermal insulation since they were constructed before 1980 when thermal insulation of new buildings was not compulsory. They also stated that there were blocks of flats in Athens where the operation of the central heating system had been stopped since the residents were unable to pay for the fuel. Energy poverty in Greece reported so far in various studies is presented in Table 1.

Table 1. Energy poverty in Greece reported in various studies

Author	Year	Energy poverty (%)
Metaxa	2015	36
Atsalis et al	2013	20-29.5
Parada et al	2016	58
Sanamouris et al	2007	21.1
European Development Bank	2016	23
Energy Institute in South-East Europe, IEA	2016	29

Source: various references

The aims of the current research are:

a) *Estimation of the changes in electricity and heating oil consumption during the recent economic crisis in the island of Crete,*
b) *Assessment of the energy poverty in Crete taking into account these changes,*
c) *Presentation of the current policies tackling energy poverty in Crete, and*
d) *Investigation of the suitable renewable energy technologies, which could be used in residential buildings in Crete, thereby reducing energy poverty.*

Limitations in the current study are related with the use of data concerning total electricity and heating oil consumption in Crete. Energy data used in this work concern energy consumed in residential buildings as well as in other private and public buildings. Additionally they include the energy consumed in agriculture and industry although these economic sectors are not well developed in Crete and their contribution in the overall energy consumption is small. Although it has been observed that during the economic crisis households in Crete have increased the use of wood fuel for heating, data related with its use in residential buildings were not available. In the current study it has been assumed that the overall changes recorded in electricity and heating oil consumption in Crete are consistent with the changes in residential buildings on the island.

2. Energy consumption in residential buildings

Residential buildings in Greece consume energy for heating, cooling, lighting, domestic hot water (DHW) production and the operation of appliances and equipment. Space heating has the highest share in the overall energy consumption in residential buildings. Parada et al, 2016 have reported that space heating has a share at 63.7% in the total energy consumption while the share of domestic hot water (DHW) production was at 5.7%. Vourdoubas, 2016 has reported that space heating has a share of 63% in the overall energy consumption while the share of DHW production was 9%. Space heating could be substantially reduced with better building insulation techniques while both heating and hot water production could be achieved with the use of renewable energies like solar energy and biomass which are abundant in Crete. The technologies of solar thermal energy for DHW production and solid biomass burning for space heating are mature, well known and cost-effective. Therefore, their use could reduce the energy expenses of households, helping them to alleviate energy poverty.

3. The recent economic crisis in Greece

During the second decade of the 21st century the global economic crisis of '07-'18 hurt the Greek economy, reducing substantially the Greek GDP which has only partly recovered since then. The average household income during this period has been reduced while the umemployement rate has been increased above 20%. At the same time the price of fuels and electricity used in households have been increased due to higher taxation and increases in crude oil prices. These factors have affected the economic capability of Greek households to cover the energy requirements in their homes resulting in higher energy poverty. The change in the Greek GDP during the period 2007-2018 is presented in Figure 1.

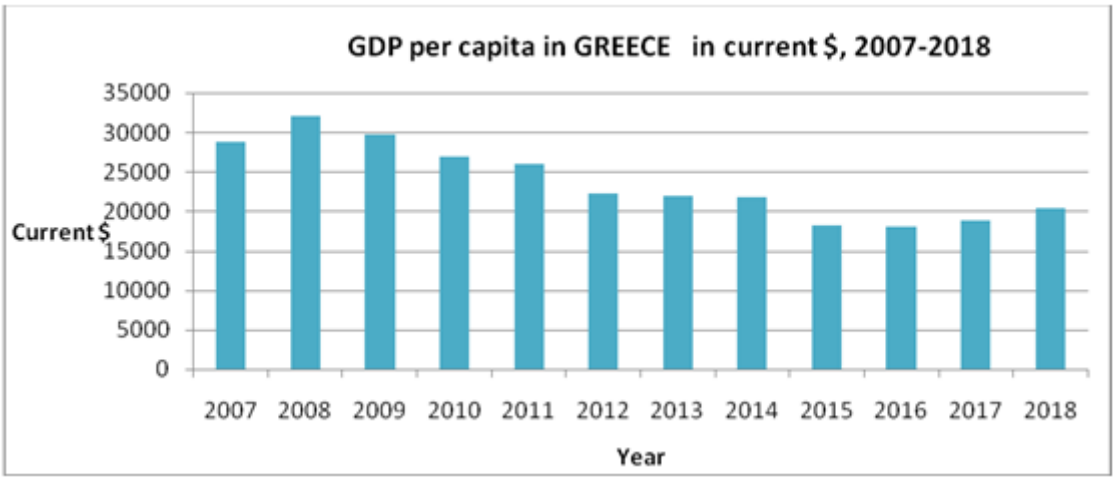

Figure 1. Greek GDP per capita in current $ during 2007-2018 (Source: World Bank).

4. Electricity consumption in Crete

Electricity consumption in Crete during 2007-2018 including both low and middle voltage, is presented in Figure 2. Electricity is used in residential buildings for lighting and operation of various electric devices. Additionally it is used for DHW production and for space heating. Electricity consumption during 2008- 2013 was reduced by 6.86% while until 2018 it recovered. The decrease in power consumption in Crete is significantly lower that the decrease of the Greek GDP in the same period, 2008-2013, when it was at 31.63%. Additionally the GDP reduction during 2008-2018 was at 36.48% while the electricity consumption has remained the same. Therefore a decoupling of the Greek GDP and the electricity consumption in Crete during the period of the recent economic crisis has been observed. It should be noted that many households during this period have replaced the use of heating oil with electricity using either heat pumps or various types of electric heaters. Some of them have been subsidized to replace their old heating systems using heating oil with high efficiency heat pumps. Others have made the replacement without subsidies since the current prices of heating oil and electricity in Greece favor the use of electricity. Others have chosen to heat only some rooms in their homes using simple electric heaters.

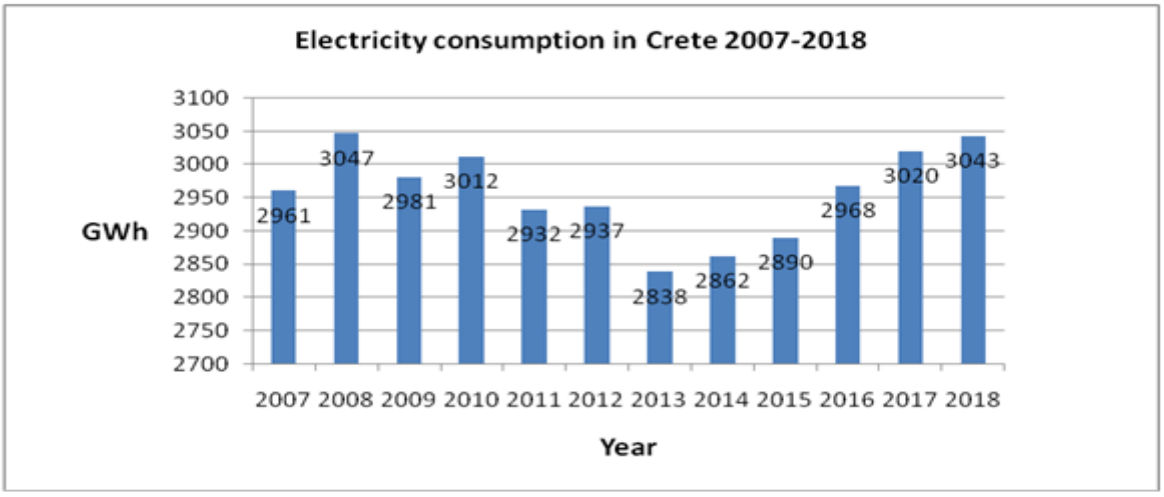

Figure 2. Electricity consumption in Crete during 2007-2018 (Source: DEDDIE)

5. Consumption of heating oil in Crete

Heating oil is used for space heating and DHW production in residential buildings. Its consumption in Crete had been sharply reduced during the period 2007-2013 by 80.16% after which it had partly recovered. Its overall reduction during the period 2007-2018 was 76.47%. At the same time the annual income of many households had been significantly reduced. During this period the price of the heating oil has been substantially increased due to high taxation imposed by the government in order to eliminate the government budget's deficit. Due to price increases the use of electricity was more attractive than heating oil for heat generation in residential buildings. Many households also replaced heating oil with wood fuel which was a cheaper fuel while many families were getting free olive tree wood from their own cultivations. Other households have installed heat pumps or electric heaters heating only some rooms for a few hours in their homes. In many cases heating of the residential buildings was not adequate for thermal comfort due to the fact that households did not have enough money to spend on heating their homes. Apart from residential buildings, heating oil was also used to heat other types of public and private buildings like hospitals, schools, hotels, offices, etc. However it is obvious from Figure 3 that its use as a heating fuel in buildings, during this period in Crete has been substantially reduced. Data regarding the use of solid biomass for heating residential buildings in Crete during this period were not available. Heating oil consumption in Crete during 2007-2018 is presented in Figure 3 while the sum of both electricity and heating oil used in the same period in Crete is presented in Figure 4.

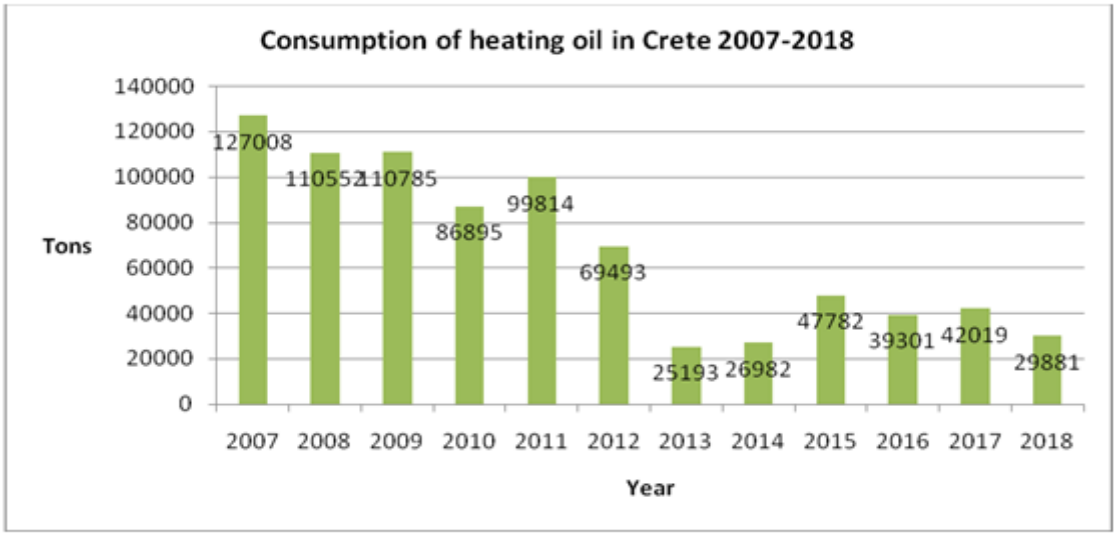

Figure 3. Consumption of heating oil in Crete during the period 2007-2018 (Source: Greek statistical authority).

The energy of both electricity and heating oil used in Crete during 2007-2018 is presented in Figure 4.

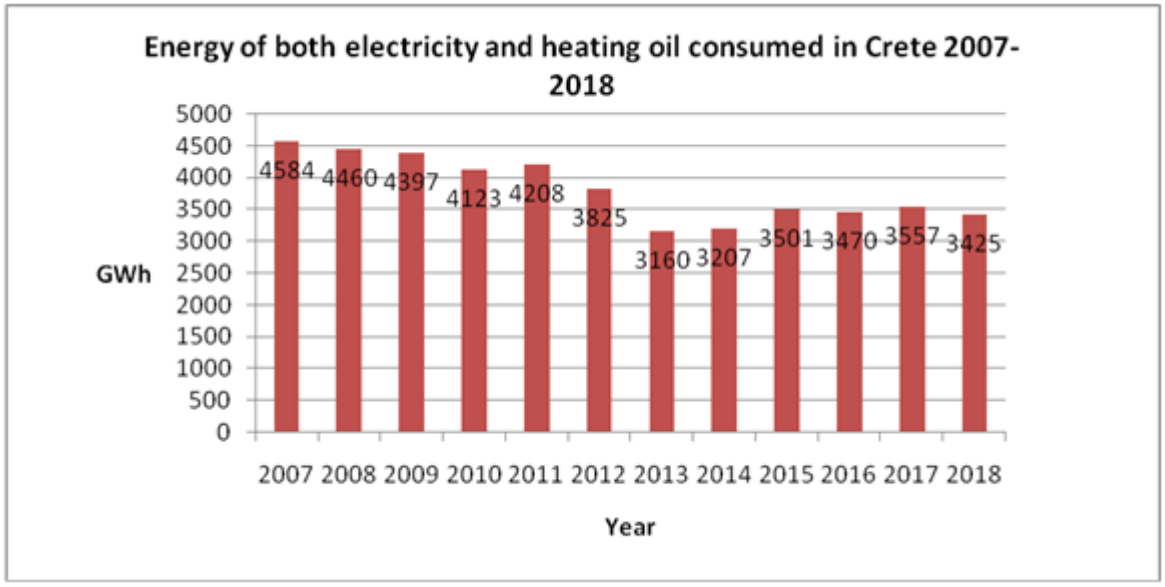

Figure 4. Energy of both electricity and heating oil consumed in Crete during the period 2007-2018., Energy of heating oil = 12.78 KWh/kg (Sources: DEDDIE and Greek statistical authority)

The changes (%) in the Greek GDP per capita, the electricity consumption in Crete, the heating oil consumption in Crete and the energy of both electricity and heating oil consumed in Crete during the economic crisis are presented in Table 2. Although the pattern of changes in electricity and heating oil consumption in Crete over this period are not consistent with the changes in the Greek GDP, it seems that the changes in total energy of both electricity and heating oil used in Crete are more consistent with the pattern of changes in the Greek GDP.

Table 2. Changes (%) in the Greek GDP per capita, electricity consumption in Crete, heating oil consumption in Crete and the energy of both electricity and heating oil consumed in Crete during the economic crisis.

Period	% change in GDP of Greece per capita	% change in electricity consumption in Crete	% change in heating oil consumption in Crete	% change of total energy both of electricity and heating oil used in Crete
2007-2010	-6.62	+1.65	-31.58	-10.06
2007-2013	-24.12	- 4.15	-80.16	-31.06
2007-2015	-36.98	+2.4	-62.38	-23.63
2007-2018	-29.50	+ 2.77	-76.47	-25.28

Source: Data from Figures 1, 2, 3 and 4

6. Existing policies for reducing energy poverty in Crete, Greece

Various policies and measures have been adopted for fighting energy poverty in Greece which are almost identical to the policies offered in other EU countries. These policies have been developed by the government for all Greek territories and they are supporting vulnerable households to cover the energy needs in their homes as well as subsidizing them for improving the energy behavior of their residential buildings. Subsidies are offered for investments in energy-saving technologies as well as in renewable energy technologies. Energy investments in residential buildings are more efficient in tackling energy poverty since they result in lower energy consumption in the buildings and lower energy bills. Renewable energy technology investments subsidized in residential buildings include both the use of solid biomass for space

heating and the use of solar thermal energy for DHW production. The measures which are currently offered in Greek households to tackle energy poverty are presented in Table 3.

Table 3. Energy measures for tackling energy poverty in Greece

Measure	Activities
Consumer protection	Special tariffs for grid electricity offered in vulnerable families; Protection from disconnection from the grid
Financial intervention	Short-term payment for purchasing heating fuel
Sustainable energy investments in residential buildings in order to improve their energy behavior	Subsides offered for energy investments in residential buildings including energy saving techniques and renewable energy technologies, net-metering regulations allowing households to generate the self-consumed electricity
Information provision	Awareness-raising campaigns, consultation regarding energy savings

Source: own estimations

7. Renewable energy technologies which could be used in residential buildings in Crete for tackling energy poverty

Installation of renewable energy technologies in residential buildings could be considered as an efficient method for tackling energy poverty since they reduce the expenses of the household payments in electricity and heating fuel bills. Their use also decreases the use of fossil fuels and the carbon emissions in residential buildings. Therefore their investment is desirable since it contributes to the achievement of multiple goals, firstly in the reduction of energy poverty, and secondly in the achievement of the carbon emissions reduction targets in Greece and the mitigation of climate change. Renewable energy sources are abundant in Crete, particularly solar and wind energy. Additionally there are many solid biomass resources due to the extensive cultivation of olive trees in the island. Various sustainable energy technologies are currently mature, reliable and cost-effective. Therefore their use in residential buildings is desirable. Solar thermal energy is used for many decades in Crete for DHW production. Solar energy with photovoltaic panels is used for electricity generation during the last decade due to the sharp decrease in the panel cost and the net-metering regulations, allowing households to generate the self-consumed electricity. Solid biomass was traditionally used for heating in Crete while high efficiency heat pumps are increasingly used in residential buildings for many reasons. It should be noted that energy used in space heating and DHW production has a share of approximately 70% in the overall energy consumption in residential buildings. The renewable energy technologies which could provide space heating and DHW in the building are mature, reliable, low cost and well proven energy technologies. Renewable energies which could be used in residential buildings in Crete to tackle energy poverty are presented in Table 4.

Table 4. Renewable energy sources and technologies that could be used in residential buildings in Crete to fight energy poverty

Energy source	Technology	Energy generated
Solar energy	Flat plate solar collectors	Heat-hot water
Solar energy	Photovoltaic panels	Electricity
Solid biomass	Burning	Heat, space heating, hot water
Low enthalpy environmental heat	High efficiency heat pumps	Heat, space heating and cooling, hot water

Source: own estimations

8. Discussion

Various studies so far have highlighted the fact the energy poverty can be better mapped with multiple indicators or a compound energy indicator. Existing studies regarding energy poverty in Greece indicated that during the period 2007-2016 a high percentage of Greek households had experienced high energy deprivation.

This is mapped in EU statistics where Greece is mentioned as a country with a high percentage of energy-poor households. There is consensus among researchers and policy makers that the increased use of sustainable energy technologies in residential buildings helps households to avoid their energy deprivation. Crete has affluent renewable energy resources which could be used with cost-effective technologies for energy generation in residential buildings, mitigating energy poverty in the island. However the current economic crisis has limited the economic ability of households to invest in these benign energy technologies. Our findings indicated that the reduction in electricity consumption during the period 2007-2013 in Crete was lower than the decrease in the same period of the Greek GDP. This has been confirmed in another study mentioning the small decrease in electricity consumption in other Greek territories during the years of the economic crisis. The sharp decrease in heating oil consumption in Crete during this period can be understood by the high taxation imposed by the government. This was an "incentive" for households to shift to other energy sources, like electricity and wood fuels, for heating their homes. Meanwhile existing studies indicated that high efficiency heat pumps were more efficient and cost-effective technology for heating residential buildings. Governmental policies tackling energy poverty in Greece are consistent with the corresponding policies in other EU countries but with limited success so far.

9. Conclusions

During the period 2007-2018, Greece was hit by a severe economic crisis, resulting in the reduction of the GDP per capita in current $ at –29.5%. At this period the electricity consumption in the island of Crete was increased by 2.77%, the heating oil consumption was reduced by 76.47% while the energy of both electricity and heating oil consumed in the island was reduced by 25.98%. The same pattern was observed in the period 2007-2013 taking into account that 2013 was the worst year of the economic crisis in Greece. The different pattern in electricity and heating oil changes over this period in Crete can be explained by the fact that electricity was cheaper than heating oil for heat generation and many consumers had changed the heating source used in homes. However, the changes in total energy consumed in Crete in both electricity and heating oil are more consistent with the changes in the Greek GDP. Although our data cannot reveal the percentage of households in Crete living under energy poverty, other studies in the country and the data reported in EU studies indicated that this percentage has been increased during the recent economic crisis and it is approximately at 30%. Policies trying to fight energy poverty in Crete are similar to those in other Greek regions and in various EU countries including consumer protection and information provision, financial interventions and sustainable energy investments in residential buildings, both in energy saving technologies as well as in renewable energy technologies. Various locally available renewable energies and cost-effective energy technologies allow the use of sustainable energies for heat, cooling and electricity generation in residential buildings in Crete. These local energy sources include solar energy, solid biomass and environmental heat. Further work regarding energy poverty in Crete should be focused on: a) Surveys with questionnaires in households regarding their arrears in utilities, the adequate supply of energy in their homes and their subjective feeling of heat comfort in them; b) The distribution of energy poverty among households with different annual incomes; c) The energy consumption and the energy expenses in households with different annual incomes; and d) The percentage of residential buildings which have installed renewable energy technologies, as well as the specific technologies used.

Acknowledgements

We would like to thank our colleagues at CIHEAM-MAICh and DEDDIE for supporting the research. We would particularly like to thank Ms. Maria Verivaki who has read the manuscript and has made positive comments.

References

Herrero, S.T. (2017). Energy poverty indicators: A critical review of methods, Indoor and Built Environment, 26(7), 1018-1031. DOI: 10.1177/1420326X17718054

Metaxa, K. (2018). Tackling energy poverty through a holistic social, environmental and energy policy, in investing in Energy Efficiency, IENE, Athens, 24 May 2018, [Online] Available: https://www.iene.eu/articlefiles/metaxa.pdf (April 10, 2020)

Parada, L., Katsoulakos, N. &Kaliampakos, D. (2016). Fighting energy poverty by going underground, Procedia Engineering, 165, 49-57. doi:10.1016/j.enbuild.2007.02.019

Parada, L. &Kaliampakos, D. (2016). Measuring energy poverty in Greece, Energy Policy, 94, 157-165. http://dx.doi.org/10.1016/j.enpol.2016.04.004

Atsalis, A., Mirasgedis, S., Tourkolias, C. &Diakoulaki, D. (2016). Fuel poverty in Greece: Quantitative analysis and implications for policy, Energy and Buildings, 131, 87-98. http://dx.doi.org/10.1016/j.enbuild.2016.09.025

Paradopoulos, A.M., Oxizidis, S. &Papandritsas, G. (2008). Energy, economic and environmental performance of heating systems in Greek buildings, Energy and Buildings, 40, 224-230. doi:10.1016/j.enbuild.2007.02.019

Koutsoulakos, N. (2011). Combating energy poverty in mountainous areas through energy-saving interventions, Mountain Research and Development, 31(4), 284-292. DOI: http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00049.1

Sardianou, E. (2008). Estimating space heating determinants: An analysis of Greek households, Energy and Buildings, 40, 1084-1093. doi:10.1016/j.enbuild.2007.10.003

Santamouris, M., Kapsis, K., Korres, D., Livada, I., Pavlou, C. and Asimakopoulos, M.N. (2007). On the relation between the energy and social characteristics of the residential sector, 2nd PALENC conference and 28th AIVC conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, September 2007, Crete, Greece.

Santamouris, M., Paravantis, J.A., Founda, D., Kolokotas, D., Michalakakou, P., Papadopoulos, A.M., Kontoulis, N., Tzavali, A., Stigka, E.K., Ioannidis, Z., Mehili, A., Matthienssen, A. &Servou, E. (2013). Financial crisis and energy consumption: A household survey in Greece, Energy and Buildings, 65, 477-487. http://dx.doi.org/10.1016/j.enbuild.2013.06.024

Middlemiss, L. & Gillard, R. (2015). Fuel poverty from the bottom-up: Characterizing household energy vulnerability through the lived experience of the fuel poor, Energy Research & Social Science, 6, 146-154. http://dx.doi.org/10.1016/j.erss.2015.02.001

Maxim, A., Mihai, C., Apostoaie, C-M., Popescu, C., Istrate, C. &Bostan, I. (2016). Implications and measurement of energy poverty across the European Union, Sustainability, 8, 483. doi:10.3390/su8050483

Dagoumas, A. &Kitsios, F. (2014). Assessing the impact of the economic crisis on energy poverty in Greece, Sustainable Cities and Society, http://dx.doi.org/10.1016/j.scs.2014.02.004

Thomson, H. &Bouzarovski, S. (2018). Addressing energy poverty in the European Union: State of play and action, EU poverty observatory. [Online] Available: https://www.energypoverty.eu/sites/default/files/downloads/publications/19-05/paneureport2018_updated2019.pdf (April 10, 2020)

Energy poverty in Europe, How energy efficiency and renewable can help (2019), Council of European Development Bank. [Online] Available: https://coebank.org/media/documents/CEB_Study_Energy_Poverty_in_Europe.pdf (April 10, 2020)

Korovesi, A., Metaxa, K., Touloupaki, E. &Chrysogelos, N. (2017). Energy poverty in Greece, Heinrich Boll Stiftung Institute, (in Greek). [Online] Available: https://gr.boell.org/en/2017/03/07/energy-poverty-greece-today-0(April 10, 2020)

Energy poverty in Greece, proposals for social innovation, (2019), Heinrich Boll Stiftung Institute, Thessaloniki, (in Greek). [Online] Available: https://gr.boell.org/en/2020/01/15/energy-poverty-greece-20 (April 10, 2020)

Boemi, S.N., Samarentzi, M. &Dimoudi, A. (2020). Research on energy behavior and energy poverty in households in Northern Greece, IOP conference series: Earth and Environmental Sciences, 410, 012083. doi:10.1088/1755-1315/410/1/012083

Panagiotopoulos, G. &Katsoulakos, N. (2015). Specification of the socioeconomic dimensions of energy demand and consumption in Greece using Georgaphical information systems. [On line] Available: from digital library Theofrastos, Department of Geology, Aristotelio University of Greece (April 10, 2020)

Boemi, S.N., Avdimiotis, S. & Papadopoulos, A.M. (2017). Domestic energy deprivation in Greece: A field study, Energy and Buildings, 144, 167-174. DOI:10.1016/j.enbuild.2017.03.009

www.statistics.gr

Kyprianou, I., Serghides, D.K., Varo, A., Gouveia, J.P., Kopeva, D. &Murauskaite, L. (2019). Energy poverty policies and measures in 5 EU countries: A comparative study, Energy and Buildings, 196, 46-60. https://doi.org/10.1016/j.enbuild.2019.05.003

The energy sector in Greece (2019). Energy Institute of South-East Europe (in Greek). On line] Available: https://www.iene.gr/articlefiles/file/meletes/iene-meleti-2019.pdf (April 10, 2020)

Vourdoubas, J. (2016). Creation of zero CO_2 emissions residential buildings due to energy use: A case study in Crete, Greece, Journal of Civil Engineering and Architecture Research, 3(2), 1251-1259.

Vourdoubas, J. (2017). Realization of a small residential building with zero CO_2 emissions due to energy use in Crete, Greece, Studies in Engineering and Technology, 4(1), 112-120. doi:10.11114/set.v4i1.2567

https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=GR

Annual report on the energy system in Crete, (2018), Hellenic Electricity Distribution Network Operator (DEDDIE), (in Greek)

Bouzarovski, S. &Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy-poverty binary, Energy Research & Social Science, 10, 31-40. http://dx.doi.org/10.1016/j.erss.2015.06.007

Vatavali, F. &Xatzikonstantinou, E. (2018). Energy Poverty in Athens during Economic Crisis, Angelus Novus publications, Athens (in Greek).