Investigating the effectiveness of projects promoting energy efficiency for energy poverty alleviation. A case study from Greece.

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Abstract

Policies providing motives for improving residences' energy efficiency potentially contribute to energy poverty alleviation. In Greece, between 2012 and 2015 a major funding scheme, called "Energy Saving at Home", was implemented that gave subsidies to citizens for increasing the energy efficiency of their houses. The total budget was 400 million euros. In the present study an analysis of a sample of households (21,000) benefitted by this project is presented. The reduction in energy consumption, the different kinds and the cost-effectiveness of interventions, and the actual contribution towards energy poverty alleviation are included in the analysis. Moreover, a critical approach to the structure of "Energy Saving at Home" and its general effectiveness is presented. This funding scheme proved to be helpful and cost-effective, especially when houses had very low energy performance and/ or were located in cold areas (like mountainous ones). However, since energy poverty alleviation was not set as a strategic aim of the project, in many cases subsidies were just used for improving the general condition of residences. Considering resource constraints, especially under the influence of the economic crisis, such projects should be orientated at energy poverty alleviation, than just reduction in energy consumption. This is also highlighted through certain examples in this study.

1. Introduction

Energy poverty is a major social problem in Greece, which has been intensified under the influence of the economic crisis (Papada & Kaliampakos, 2016). The Greek State has implemented policies for supporting vulnerable households' energy supply and for improving residences' energy performance.

Regarding energy supply, two main measures have been applied:

<u>A) Social Residential Tariff:</u> From October 2010, households with low family income (less than 12,000 €/year), families with three or more children, unemployed, people with disabilities and other vulnerable groups pay significantly reduced tariffs for purchasing electrical energy, from 0.045 €/kWh to 0.075 €/kWh (PPRC, 2018). In March 2015, an extra measure was implemented; households unable to pay their electricity bills can use up to 300 kWh of electricity without charge.

B) Heating oil subsidy: Since November 2012, households are facilitated in purchasing heating oil, through subsidies in certain quantities of heating oil, depending on households' income, floor area of the residence and climatic zone. Nowadays, the budget of the subsidies has been cut off by 50% compared to 2012. Unlike the Social Residential Tariff, consumers purchase the necessary heating oil at the current market prices and after some months they get the subsidy, as a refund. This is a problematic aspect of this measure. Moreover, in the first phase of this measure's application, problems regarding the categorization of the country into climatic zones were observed, which led to underestimation of energy needs, especially in mountainous areas (Katsoulakos & Kaliampakos, 2014).

These measures aim at making energy products more accessible to vulnerable households. In other words, they act as fuel price reduction. In the present paper, another policy is studied, that aimed at lowering energy consumption, the project under the name "Energy Saving at Home" - ESH. In general, this project provided financial motives to households for implementing energy efficiency measures and interventions in their residences. This project was implemented from 2011 until 2015 and co-founded by the Greek State and the European Union, through the European Regional Development Fund (ERDF). The initial, total budget of the project was 396 million euros, but, finally, the amount spent almost reached 550 million euros. The number of households benefitted from the project exceeded 30,000 (MENVEN, 2011).

The main characteristics of the ESH project are summarized below (MENVEN, 2011) (Tsabras, 2018):

- Eligible residences for funding energy saving interventions were the ones belonging to the energy classes D, E, F, G according to the Greek Regulation for the Energy Performance of Buildings, called KENAK (TEE, 2017).
- The maximum budget of interventions was 15,000 € per residence
- The eligible energy saving/ efficiency interventions were the following
  - ✓ Replacement of windows (frames and glazing), including shading systems
  - ✓ Insulation of walls and roofs
  - ✓ Upgrading of the systems for space and water heating (installation of heat pumps, replacement of old heaters with new ones etc.)
  - ✓ Installation of solar thermal systems for water heating
  - ✓ Autonomous heating with natural gas heaters
  - ✓ Installation of thermostatic vanes, compensation circuits etc.
  - ✓ Biomass systems in areas outside the prefecture of Attica
- Four categories of households according to their income were defined, which were eligible for different financial motives, regarding the implementation of the energy saving interventions. The income categories and the corresponding financial motives were the following:
  - ✓ Category A1 - Personal annual income less than 12,000 € or family annual income less than 20,000 € / 70% subsidy and 30% interest-free loan
  - ✓ Category A – Personal annual income less than 22,000 € or family annual income less than 40,000 € / 30% subsidy and 70% interest-free loan

- Category B - Personal annual income between 22,000 € and 40,000 € or family annual income between 40,000 € and 60,000 € / 15% subsidy and 85% low-interest loan
- Category C: Personal annual income between 40,000 € and 60,000 € or family annual income between 60,000 € and 75,000 € / 100% low-interest loan

- The eligible types of residences for funding were detached houses, individual apartments and block of flats.

It should be mentioned that the ESH project did not aim at energy poverty alleviation. Energy poverty was not mentioned in the technical guide of the project. The project's aim was the reduction in energy consumption, in the direction of achieving the national targets regarding energy saving.

Figure 1 illustrates the money spent from the Greek State in the period 2012 – 2014 for supporting energy efficiency interventions and for heating oil subsidies. Almost 1.2 billion euros were spent for energy efficiency interventions and oil subsidies during this three-year period, the hardest years of the economic crisis in Greece.

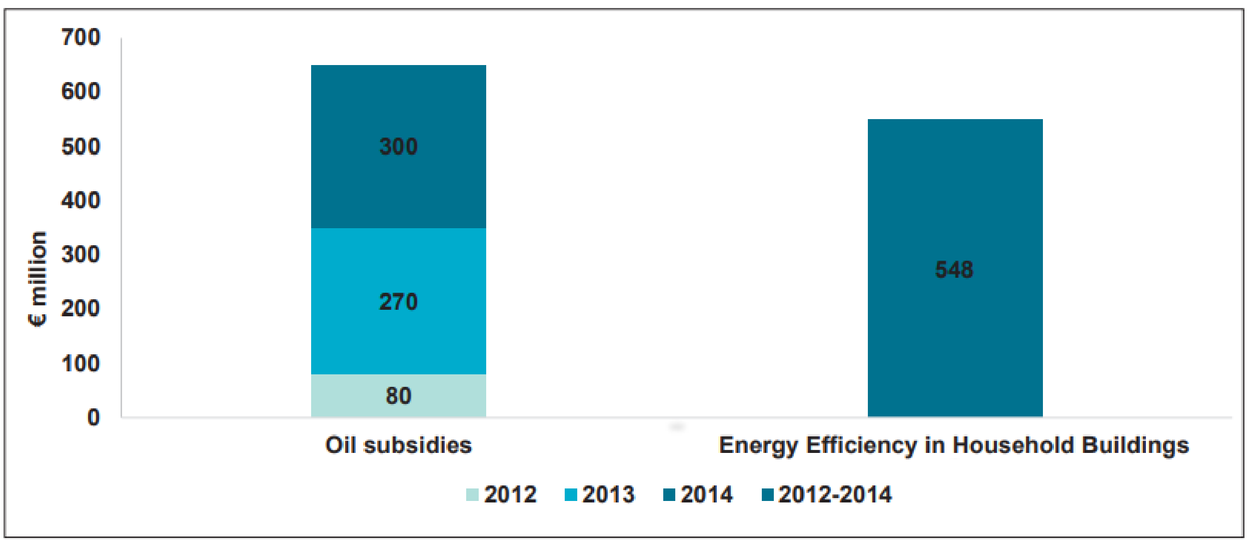

Figure 1. Public expenditure on oil subsidies and energy efficiency interventions in households, in Greece, during the period 2012 – 2014 (Atanasiu, et al., 2014).

The present paper focuses on the ESH project and analyzes its major characteristics based on a database from the Ministry of Environment and Energy related to the project. Based on the analysis, conclusion regarding the cost-effectiveness of ESH and its relation to energy poverty alleviation are reached.

2. Data and Methods

2.1 Database description

The main source of data for approaching the ESH project was a database containing about 21,000 records related to households benefitted from the project and the energy saving interventions applied. The database covers the period from March 2013 to October 2013 and the records represent about 2/3 of the total benefitted households. Hence, the sample is big and representative of the ESH project. The database included the following information:

- Type of residence
- Floor area of residence
- Climatic zone of residence[1]
- Energy class before and after the interventions[2]
- Primary energy consumption before and after the interventions
- Budget of energy saving interventions applied
- Type of energy saving interventions applied
- Household category regarding the financial motives provided

Although such a database could include more technical details, it allows the analysis of ESH project at a good level.

2.2 Database consolidation

This was the most crucial step of the procedure, in order to make an analysis based on reliable data. The initial database contained more than 21,000 records. Unfortunately, there were mistakes in the database and a set of interventions/ corrections was necessary. Firstly, obvious mistakes were identified and corrected (in cases it was possible) such as:

- Reverse records (initial energy class higher than the energy class after the interventions)
- Mistakes in number formats
- Residences' floor areas equal to zero
- Absence of interventions' costs data

Then, a check for non-obvious mistakes was conducted, which was based on:

- Setting energy consumption reduction limits, when a house was upgraded from the energy class "I" to the energy class "j"
- Creating frequency histograms of the energy consumption values of EnC 1, in order to identify unreliable records

Regarding the energy consumption reduction limits, the provisions of KENAK were used, which determine the upper and lower energy consumption limits of a residence, in order to rank its energy class, with respect to the corresponding energy consumption of the "reference building". In order to ensure that the change to the energy class of a house was properly recorded, the change in energy consumption (between EnC1 and EnC2), had to range between a lower and upper limit. For instance, if a house – after the interventions – is upgraded from class F to class D, the reduction in energy consumption has to be between -19.8% and -48.4%. Another example is shown in Figure 2, for better understanding how the limits are estimated. The symbol RR refers to the energy consumption of the reference building.

Regarding the lowest energy class, G, there is no upper limit in energy consumption reduction, when upgrading from this class to another, since class G has no lower limit regarding its energy

[1] The climatic zones in Greece for energy performance calculations, according to KENAK, are four A, B, C and D. The colder climatic zone is D and the warmer is A (TEE, 2017).

[2] The energy class of the residences, as well as their primary energy consumption is retrieved by energy certificates, issued following the procedure of energy audit, before and after the energy saving interventions. This procedure was compulsory for participating in the ESH project.

consumption in comparison with the reference building. Similarly, there is no upper limit when upgrading from an energy class to the highest one, which is A+. Moreover, if a residence goes from an energy class to the next (e.g. from D to C), there is no lower limit for the reduction in energy consumption. Theoretically, if a house's energy consumption is slightly over the lower limit of the energy class, in which it belongs, with just a small improvement in energy performance, it can "pass" to the next energy class. Hence, again theoretically, such a change in energy consumption may be very close to zero. This was an importance weakness of the ESH project.

The ESH project also allowed a house to remain at the same energy class, provided that the energy consumption after the interventions was 30% lower than before the interventions. So, the limits when remaining at the same energy class were also determined. This is illustrated by an example in Figure 3.

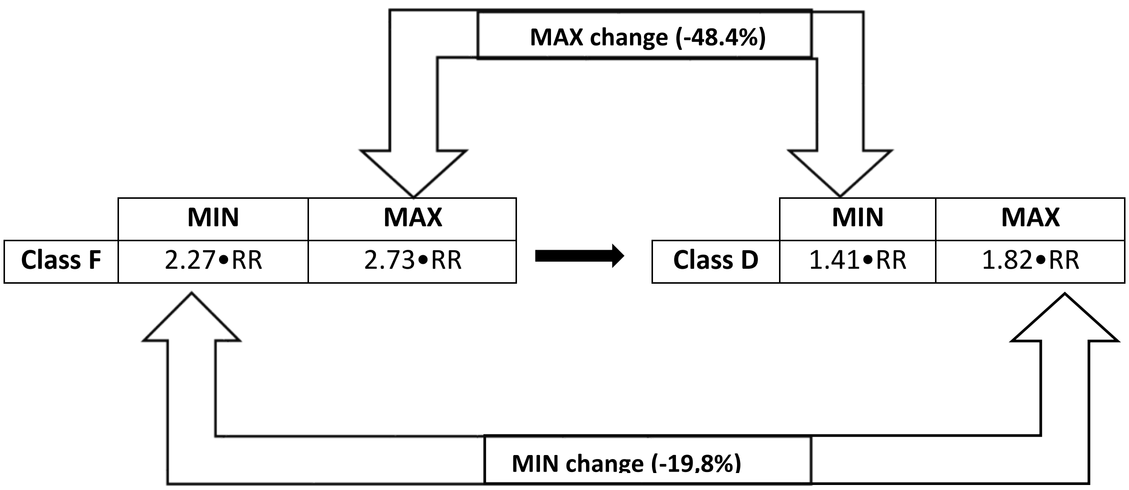

Figure 2: Example of calculating lower and upper limits of energy consumption change when a residence is upgraded from energy class F to energy class D.

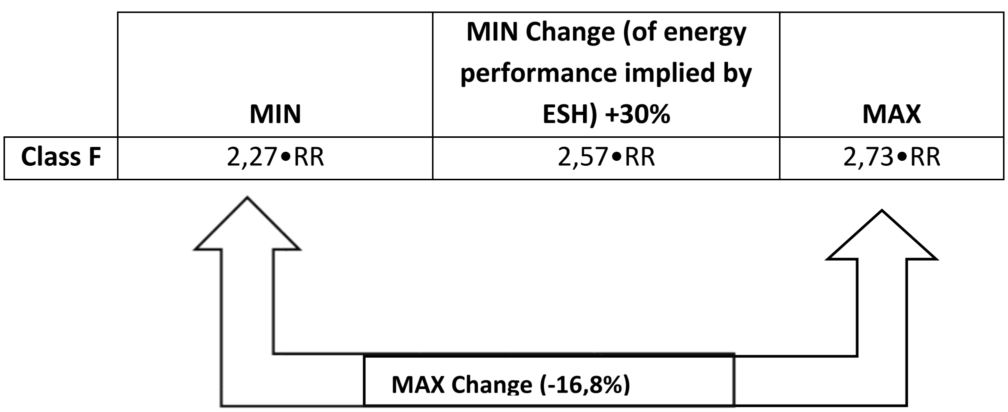

Figure 3: Example of calculating lower and upper limits of energy consumption change when a residence is upgraded and remains in the same energy class (F).

After the corrections based on the abovementioned elements, there were still records in the database characterized by very big (and sometimes very small) values of energy consumption. Especially in the case of energy class G, where no upper limit of energy consumption change exists, the values and the change in energy consumption were problematic in a number of records. In order to overcome this issue, frequency histograms were created for every energy class and every climatic zone. All of them presented distribution profiles near to the normal distribution. From these distributions, 5% of the records were excluded, the outliers. Following this procedure, Table 1 was composed, which presents the "acceptable" primary energy consumption values of each energy class (eligible for receiving subsidies for energy saving interventions) in the four climatic zones of Greece.

The whole dataset was ranked into three categories, according to the abovementioned. A rating, 1, 2 or 3, was given to each record, with respect to its reliability. The highest ranking, 3, was attributed to records that passed all the reliability checks. When a record was problematic but after a correction it presented values compatible with the limits of Table 1, it was ranked with 2. Records that remained out of the limits of Table 1 after the corrections, were ranked with 1. Records ranked with 2 and 3 were kept for further analysis. In this way, the final number of records which were analyzed was nearly 19,500.

Table 1. "Acceptable" upper and lower primary energy consumption values of the various energy classes in the four climatic zones of Greece

(Values in kWh/m²)		ENERGY CLASS							
		D		E		F		G	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
CLIMATIC ZONE	A	70	180	100	270	130	360	160	600
	B	90	290	110	360	140	400	160	660
	C	100	370	140	410	140	500	210	820
	D	100	400	140	430	140	560	240	880

2.3 Data analysis

After the data consolidation, the records kept in the database, were edited through simple statistical analysis, in order to estimate:

- The percentage of energy savings achieved after the interventions applied
- The energy savings achieved in absolute terms
- The distributions of energy savings in energy classes and climatic zones
- The energy savings achieved according to the type of interventions
- The average total cost of each type of energy saving interventions
- The effectiveness of interventions (presented below) with respect to different aspects of ESH project
- The relation between various aspects and characteristics of the ESH project and the vulnerability of households to energy poverty

For gaining a better understanding of the ESH project's performance, the "energy saving interventions effectiveness" was also used (€/kWh), defined as follows:

$$P = \frac{C}{PEC_{before} - PEC_{after}} \quad (1)$$

Where:

C: the cost of the interventions applied

PEC_{after}: the primary energy consumption of the residence after the energy saving interventions

PEC_{before}: the initial primary energy consumption of the residence

Regarding the energy saving interventions, the following symbols have been used, for reasons of brevity:

- Thermal insulation in walls/ roofs/ floors: I
- Replacement of window frames: W
- Interventions in the heating system: H

In cases of combinations of interventions, for example insulation and replacement of boiler, the symbol used is I-H.

3. Results and Discussion

In this Section the main findings of the study are presented and discussed.

3.1 Energy savings

In Figure 4, the average percentage of energy savings achieved – after the interventions founded by the ESH - is presented, with respect both to the initial energy classification of the residences and to the climatic zones. The percentage of energy savings is defined as:

$$PES = \frac{PEC_{after} - PEC_{before}}{PEC_{before}} \quad (2)$$

It can be observed that, in general, the percentage of energy savings rises in the colder climatic zones. However, in the climatic zone B, the percentage of energy savings is lower that in zone A and, in total, it is the lower among all climatic zones. This may be explained if we consider the fact that the greatest urban centers of Greece belong to the climatic zone B. In the urban centers of Greece, as a rule, houses are in better situation and newer than in semi-urban and rural areas. Hence, the average percentage of energy savings may be lower in the urban centers, since the initial primary energy consumption is also lower in these areas. In Figure 5, the average reduction in primary energy consumption (in absolute terms) is presented. In this case, the increase in energy savings in colder climatic zones is more clearly depicted. It is also explicit that energy savings are increased in houses that belong to lower energy classes.

Another interesting element is to explore the how the total energy savings are distributed among energy classes and climatic zones. The relevant data are summarized in Table 2. Three quarters of energy savings come from energy efficiency interventions in houses which were classified in energy class G, the one with the lowest energy performance. Almost 70% of the energy savings come from houses located in the areas belonging to climatic zones C and D. These climatic zones include the coldest part of the country; northern Greece and mountainous areas.

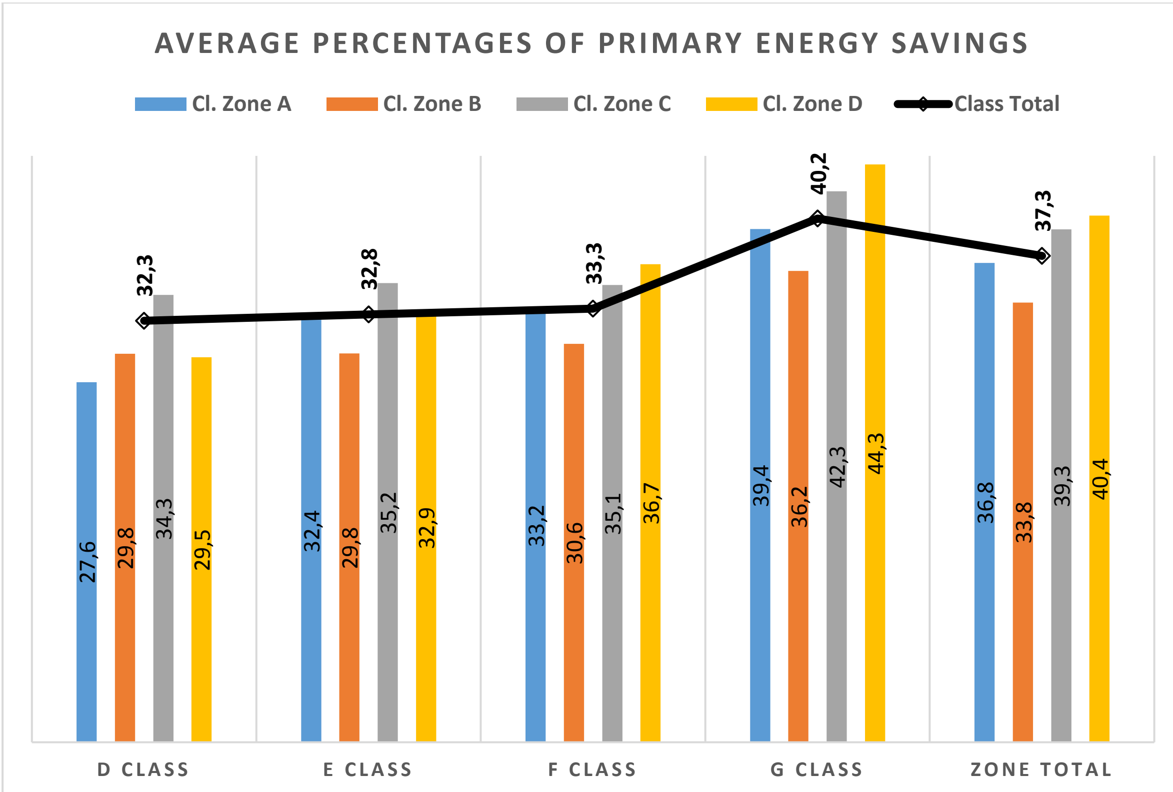

Figure 4. Average percentages of energy savings with respect to the initial energy classification of households and the climatic zones

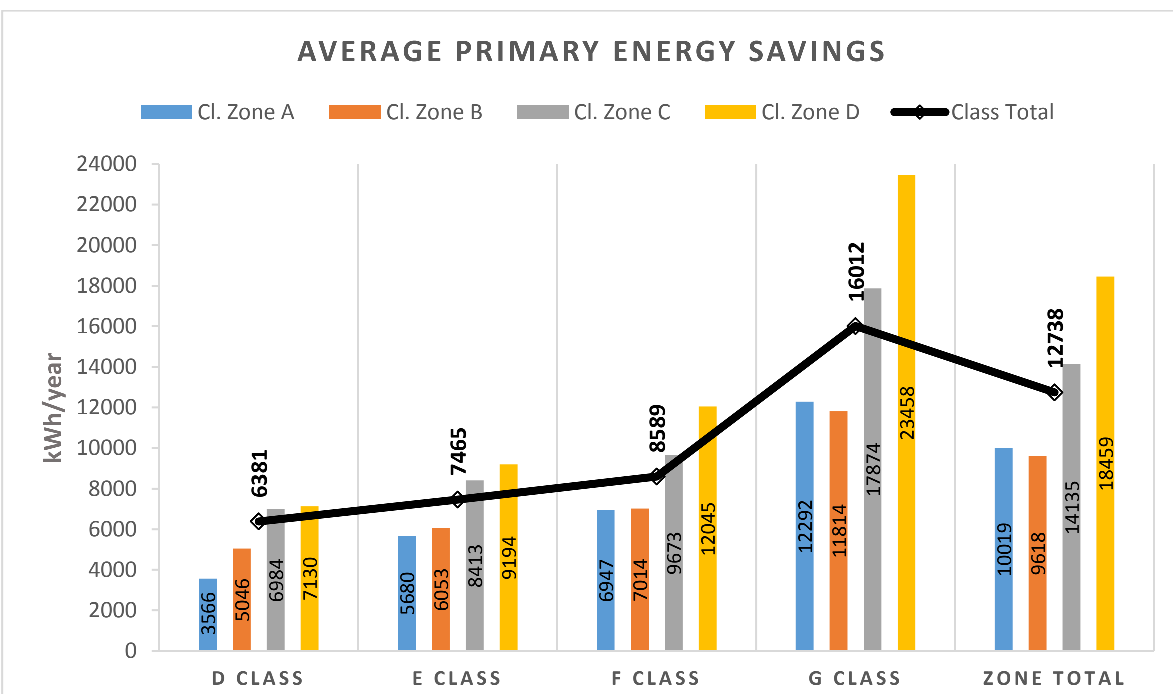

Figure 5. Average energy savings, in kWh/year, with respect to the initial energy classification of households and the climatic zones

Table 2. Percentile distribution of total energy savings achieved by ESH with respect to the initial energy class of the benefitted houses and the climatic zones

Initial energy class of the residence	D	E	F	G
Distribution of total energy savings	4.1%	8.1%	11.9%	75.9%
Climatic zone	A	B	C	D
Distribution of total energy savings	6.0%	26.4%	50.9%	16.7%

Finally, the average annual energy savings according to the type of interventions applied, are presented in Figure 6. As it was expected, when a household implements multiple interventions the energy savings increase. However, it should be highlighted that thermal insulation in walls/ roofs/ floors has the greatest impacts regarding energy savings. It seems that a building shell with low thermal conductivity is the key-point for reducing energy consumption.

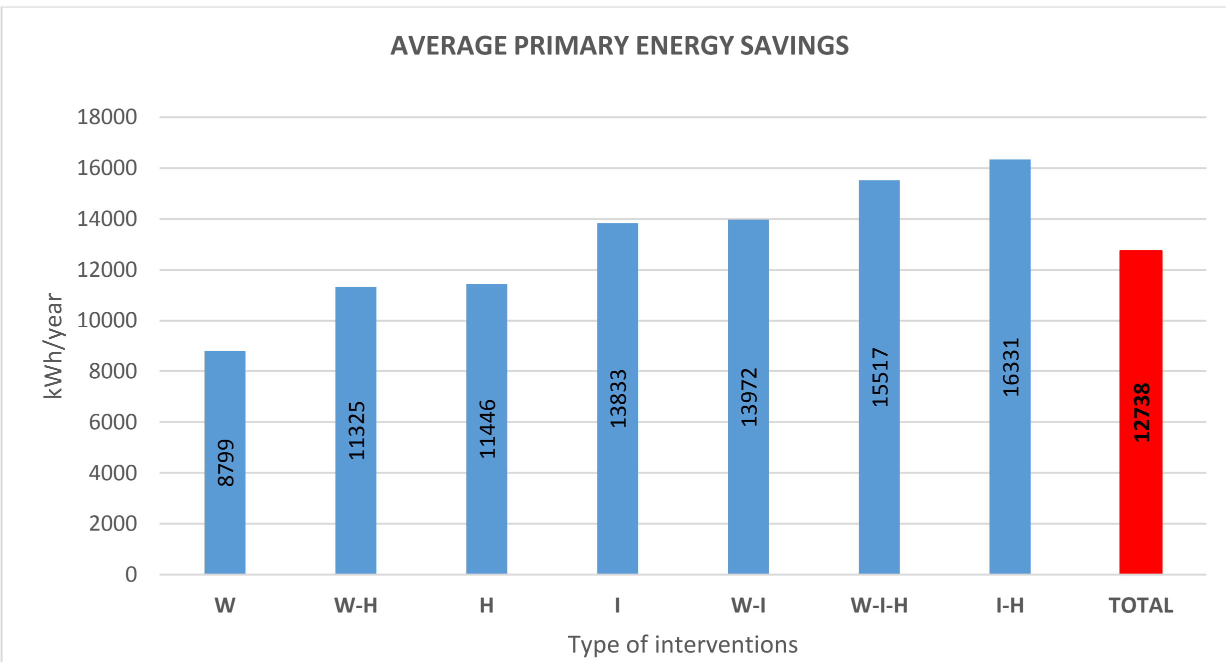

Figure 6. Average energy savings, in kWh/year, with respect to the type of energy efficiency interventions applied to the households benefitted by the ESH project

3.2 Cost effectiveness of interventions

In Figure 7, the average total cost of each type of energy saving interventions is presented. The green bars represent the average "partial" cost of each of the three basic categories of interventions (I, W, H), which is calculated in all cases of interventions that include I, W or H. The average total cost increases when different types of interventions are combined and so, the highest total cost is observed in the I-W-H case, which includes all types of interventions.

The average partial cost of I, W and H is lower than the average cost in cases where only I, W or H were applied. This, practically, means that when combinations of interventions were applied, the cost per type of intervention was lower. The available data could not provide a specific explanation for this. However, two reasonable assumptions can be made:

a) In cases of combined interventions, which have higher total cost, contractors provided better deals to household owners.
b) The maximum budget, subject to subsidies, was 15,000 euros. So, in cases of combined interventions, in order not to exceed this limit, household owners applied partially each type of basic intervention. For example, they put thermal insulation only to the roof and not to the walls.

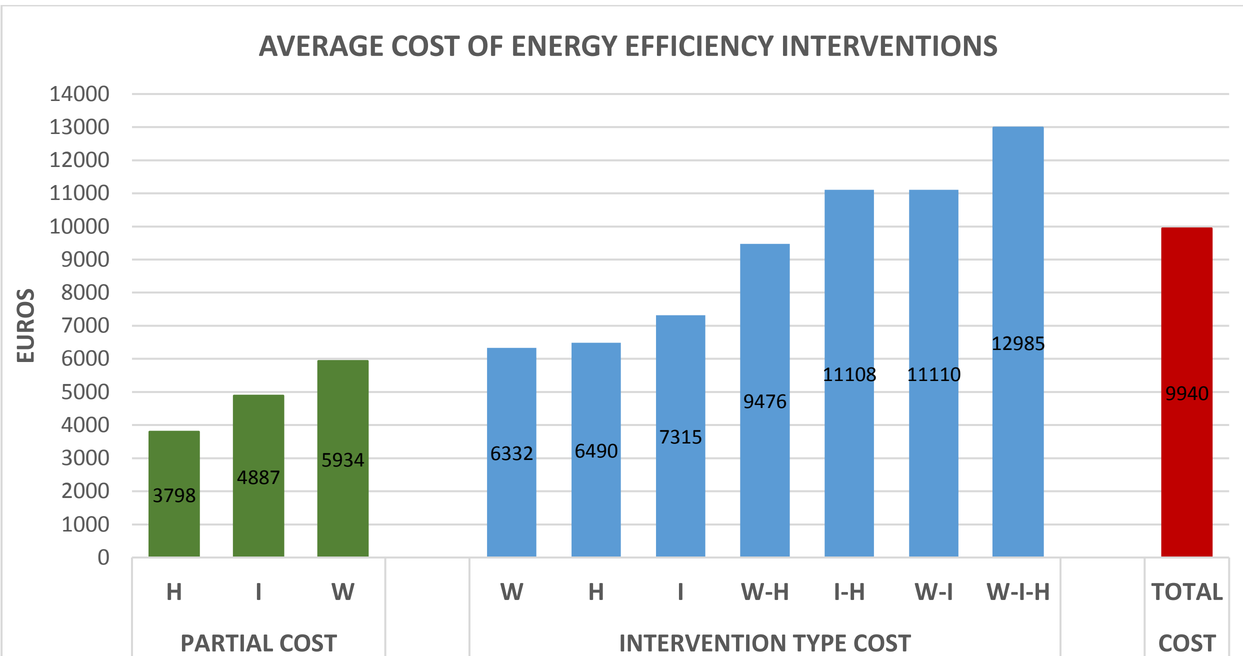

Figure 7. Average cost of energy efficiency interventions applied in the ESH project.

The investigation of the cost effectiveness of the energy saving interventions is facilitated by using "P", given by Equation (1). The lower the value of P, the higher the effectiveness of the interventions. Using P, the effectiveness of the interventions could be investigated for each household that benefitted from the ESH project. Moreover, P can be calculated for several sub-categories of the database and thus, reach useful conclusions. In Figure 8, the values of P are presented with respect to several factors. In total, within the ESH project, the average cost of each kWh of primary energy savings was 0.78 €. This is an important indicator of the ESH project's economic efficiency. The final energy consumption is related to primary energy consumption by Equation 3 (TEE, 2017):

$$PEC = FEC \cdot cf \tag{3}$$

Where:

FEC: Final energy consumption

cf: conversion factor (1.05 for natural gas/ lpg, 1.10 for heating oil, 2.9 for electrical energy, 1 for biomass, 0.7 for district heating)

Hence, the value of P would be slightly larger when reduced to FEC. It is reminded that FEC is directly connected with energy expenses. By considering the household's energy mix in the same period, when ESH was implemented, the average cf of the Greek houses was 1.08 (ELSTAT, 2013). Therefore, in terms of FEC, the avoidance cost per kWh was 0.84 €, within the ESH project. In order to gain a comparative perspective, the average cost for covering household's energy needs in the period 2011-2013 was 0.09 €/kWh and the cost of using heating oil, which is the main fuel households are using in Greece, was 0.105 €/kWh. Therefore, the cost per kWh of energy savings, which should be highlighted that is a one-off expense, is rather advantageous. The repayment of the investments occurs in less than ten years, and this applies for the average Greek household and for interventions whose lifetime exceeds 25 years. Moreover, it is obvious that energy saving investments, since they refer to one-off expenses, are a better choice than heating oil subsidies, especially at a mid- to long-term basis.

In Table 3, the influence of various factors, related to energy consumption and performance, on P is summarized in a qualitative way, in order to gain a broader view.

Table 3. Influence of several factors on the effectiveness of energy saving interventions (P) in the ESH project.

	POSITIVE INFLUENCE +	**NEGATIVE INFLUENCE -**
Initial energy classification	Low energy class	High energy class
Improvement of energy performance	High energy consumption reduction, up to the "limits" of energy class B	Slight energy consumption reduction / improvement to energy class B+ or higher
Climatic conditions	Cold/ severe climatic conditions	Mild climatic conditions
Type of residence	Detached house	Independent apartment (in block of flats)
Residence size	Big floor area	Small floor area
Type of interventions	Heating system and/ or thermal insulation	Windows

Finally, a Map was composed (Figure 9), in order to have a spatial view of the cost effectiveness of energy saving interventions, at municipal level, all over Greece. It is profound that in the northern part of the country effectiveness was higher, in comparison with the southern part. In the main urban centers effectiveness lowers, the examples of Athens, Patras and Heraklion are indicative. Even in areas with higher efficiency, urban centers present lower efficiency than their neighbouring areas, like in the cases of Thessaloniki and Ioannina.

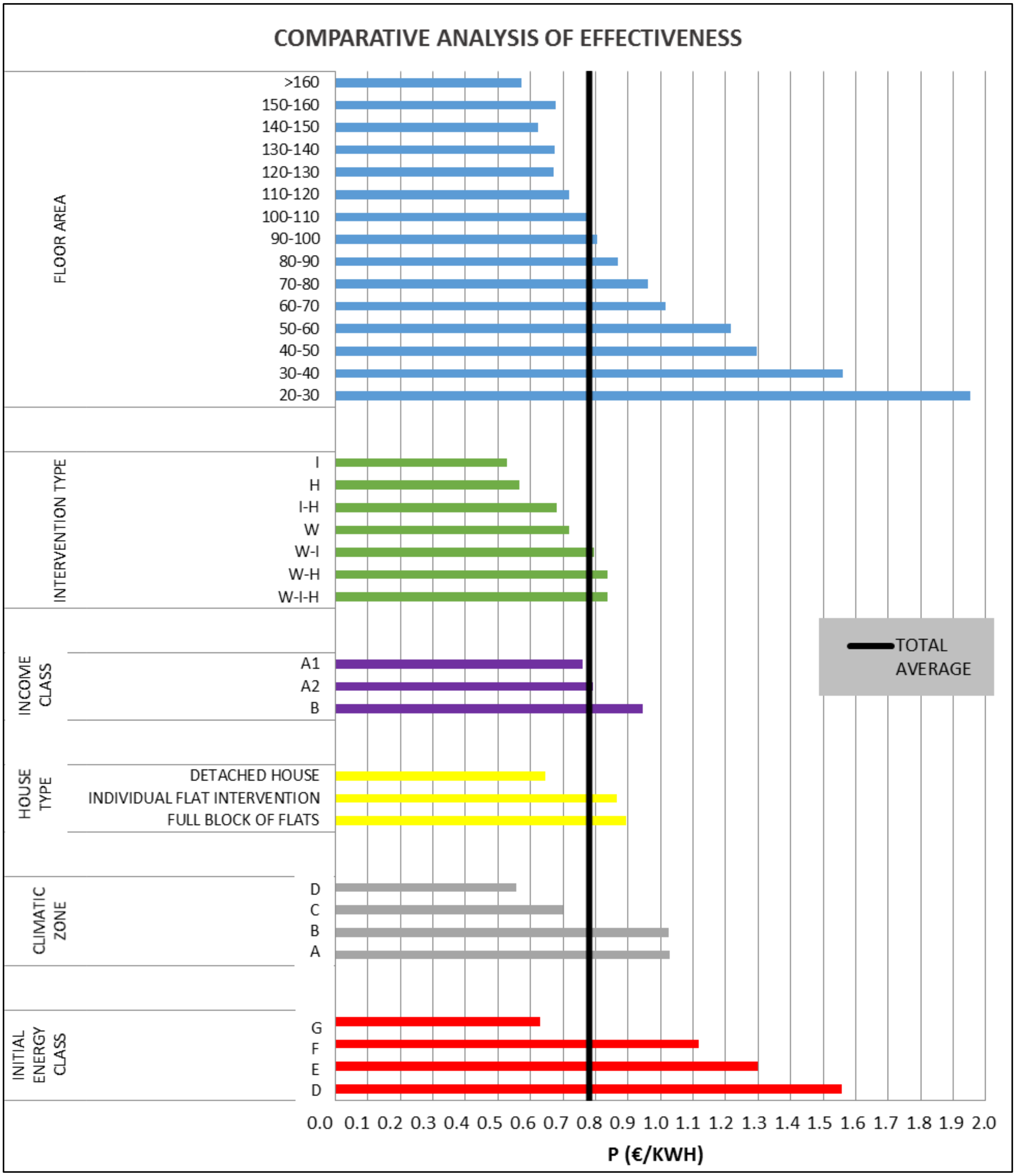

Figure 8. Cost effectiveness of energy efficiency interventions in the ESH project, with respect to various parameters.

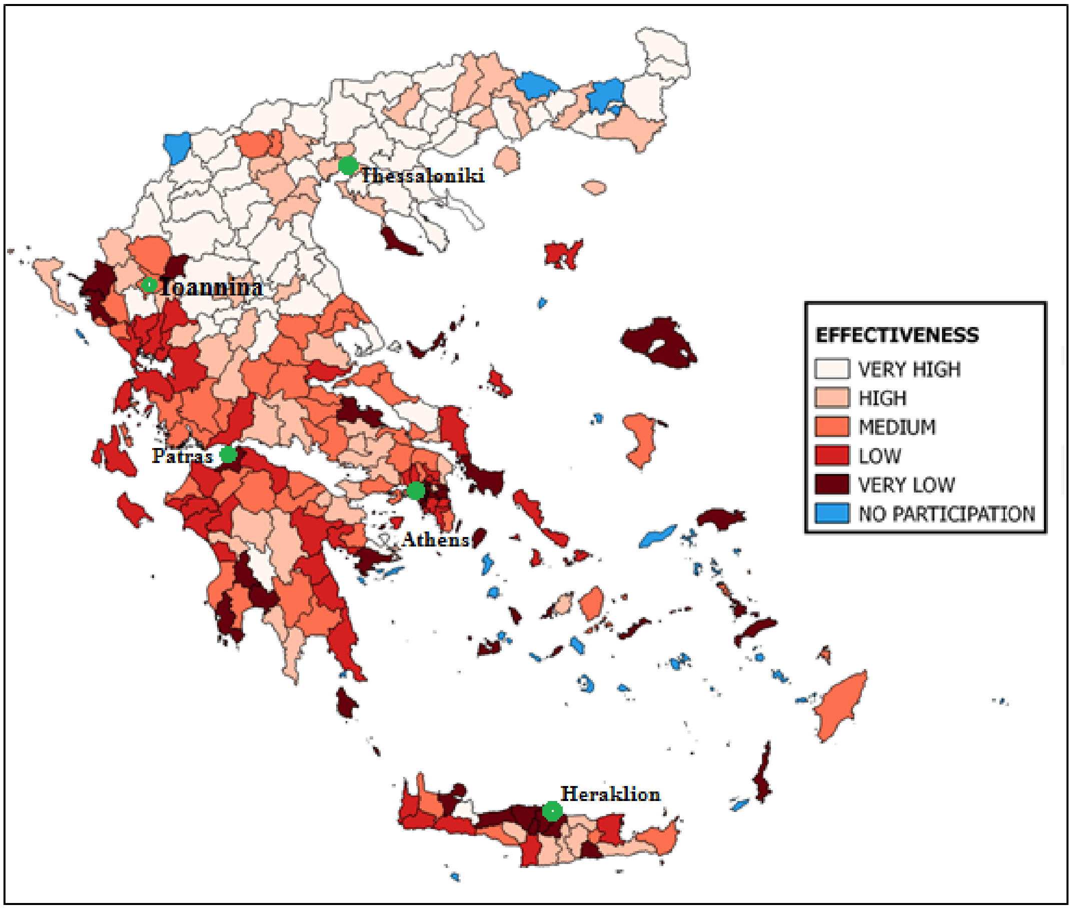

Figure 9. Map showing the effectiveness of interventions applied within the ESH project in the municipalities of Greece.

3.3 ESH project and energy poverty

In the postgraduate thesis of Tsabras (2017) a semi-qualitative, predictive model regarding energy poverty vulnerability in Greece was developed. The model ended up with an index which expressed the likelihood of energy poverty occurrence; the Energy Poverty Potential Index (EPPI). For consistency purposes, the EPPI was estimated for the same time-period, when the ESH project was implemented. The EPPI, at municipal level, is presented in the Map shown in Figure 10.

In Table 4, data related to areas and houses in which ESH was implemented with the respect to their vulnerability to energy poverty are presented. From the column of Table 4 that shows the municipalities, which did not participate in ESH, it is shown that areas more exposed to energy poverty had stronger interest in benefitting from ESH. The distribution of houses benefitted from ESH shows that:

- The share of houses at high and very high risk of energy poverty is higher than their share in the residences' distribution
- Almost 55% of the benefitted houses are at low and very low risk of energy poverty

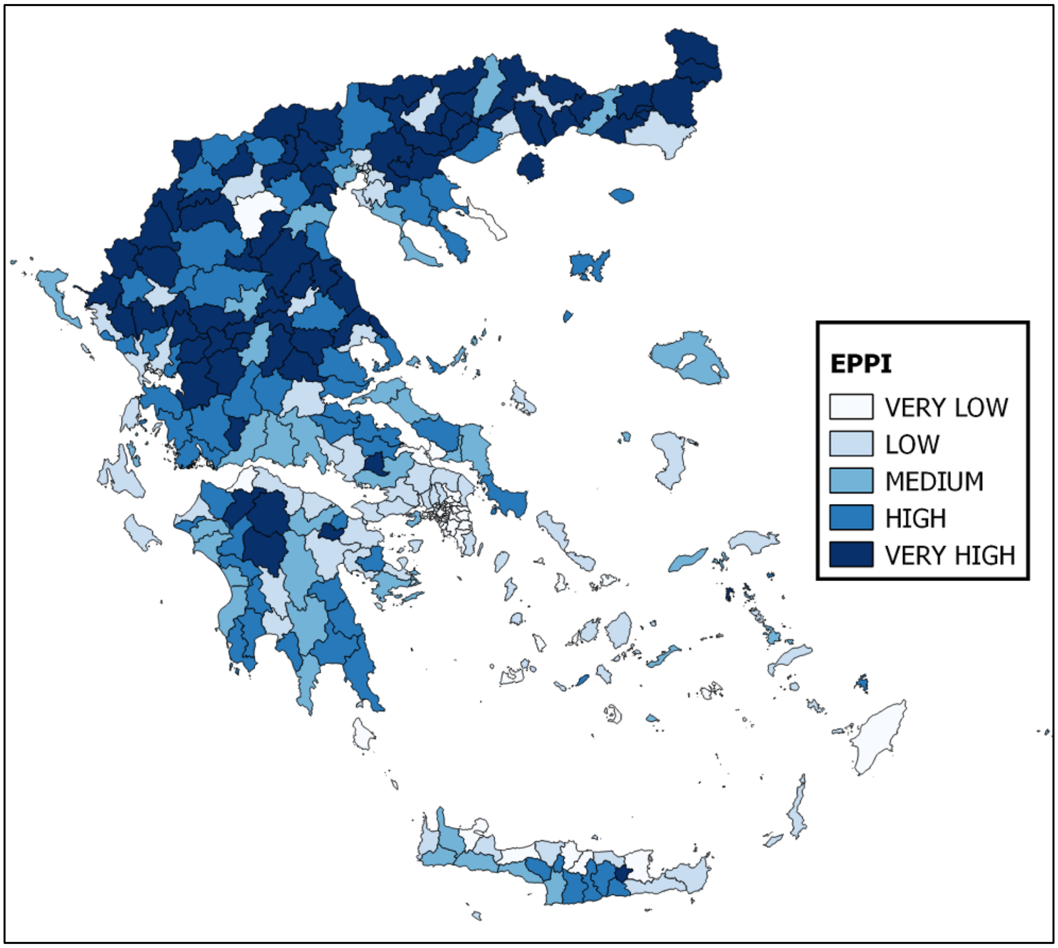

Figure 10. Map showing the EPPI (Energy Poverty Potential Index) in Greece, at municipal level.

Table 4. Distribution of municipalities and houses with respect to their vulnerability to energy poverty. Distribution of municipalities not benefitted from ESH and of houses benefitted from ESH, with respect to their vulnerability to energy poverty.

		MUNICIPALITIES		ESH (Energy Saving at Home) Project	
		Number	Number of houses	Number of municipalities not taking part in ESH	Number of beneficiaries in database
		325	4,121,768	50	19,623
EPPI (Energy Poverty Potential Index)	Very Low	20.3%	44.5%	6%	27.3%
	Low	24.3%	24.9%	42%	27.8%
	Medium	14.2%	10.9%	20%	15.3%
	High	19.4%	10.3%	18%	15.1%
	Very High	21.8%	9.4%	14%	14.4%

Taking the abovementioned into consideration, despite the greater interest of areas exposed to energy poverty in ESH, still most of the beneficiaries are at low risk of energy poverty. This is partly explained by the fact that households in urban centers (which represent more than 60% of the country's population) present, mainly, low EPPI. Yet, it should not be neglected that households in energy poverty situation, in most cases, face broader economic difficulties and so, it is not easy for them to apply energy saving interventions – even in the case where 70% of the expenses are subsidised.

In Table 5, several aspects of ESH with respect to the vulnerability of houses to energy poverty is presented and useful findings are coming up. The A1 category of beneficiaries refers to people with low incomes (up to 12,000 € annual personal income or up to 20,000 € family income). It is clear that people with low incomes were more active in participating in ESH. The same applies for households belonging to the lowest energy performance class (G). Moreover, the number of category A1 beneficiaries and the percentage of households with low energy performance, which participated in ESH, increase when EPPI becomes more adverse. The situation is similar regarding the parameters of energy savings and interventions' cost effectiveness. More specifically, households at high energy poverty risk present higher percentages of energy savings and higher cost effectiveness of interventions, compared to households at low energy poverty risk.

Table 5. Investigation of several aspects of ESH with respect to vulnerability of households to energy poverty

		Municipalities	ESH (Energy Saving at Home) Project			
			A1 Category of beneficiaries	**Share of Energy class G**	**Average energy savings**	**Cost effectiveness of interventions - P (€/kWh)**
TOTAL		325	36.3%	60.4%	-37.3%	0.78
EPPI (Energy Poverty Potential Index)	Very Low	20.3%	27.1%	55.6%	-35.1%	1.03
	Low	24.3%	35.5%	57.9%	-37.7%	0.82
	Medium	14.2%	37.6%	59.6 %	-35.9%	0.78
	High	19.4%	42.1%	64.0%	-39.6%	0.68
	Very High	21.8%	47.6%	71.6%	-39.8%	0.59

4. Summary and Conclusions

Following the findings presented in the present study, some basic points and conclusions are summarized below regarding the results of "Energy Saving at Home" project implementation:

- Energy savings are higher in colder climatic zones and in cases of houses whose energy class is low. Combination of energy saving interventions imply greater energy consumption reduction, but thermal insulation is the intervention with the best performance.
- The average expenses for upgrading the energy performance of residences was about 10,000 € per household.
- The average cost per kWh of primary energy savings was 0.78 €. This makes the investments in energy efficiency viable and attractive, especially in comparison with heating oil subsidies.
- Households at high risk of energy poverty were more strongly interested in taking part in the ESH projects. These households achieved higher energy savings within the project, while the cost effectiveness of their energy efficiency interventions was 43% higher than the corresponding effectiveness of homes at low risk of energy poverty.

The effects of the economic crisis regarding energy poverty in Greece have been intense. Many households are exposed to energy poverty and face difficulties in covering sufficiently their energy needs. The first project providing motives for applying energy efficiency measures can be characterised successful, as far as energy savings and cost effectiveness of interventions are concerned. It seems that such projects are particularly suitable and beneficial for households that are highly vulnerable to energy poverty. However, there are indications that many of these households are not able of taking part in such projects, because they cannot pay by themselves even small parts of the necessary budget for energy upgrade of their homes. This should be carefully considered in the forthcoming projects, which will provide subsidies for energy efficiency interventions, in order to gain positive results in energy poverty alleviation.

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