Evaluations of energy upgrading interventions in social housing neighbourhoods in Greece: an approach that takes into account residents' views

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Abstract. The European Union (EU) has committed to actions aimed at the energy efficiency of buildings, with a focus on the domestic sector. Most residential buildings in Greece are classified in the lowest energy categories, while the government attempts to upgrade them energy wise, through state subsidy programs. This study aims to evaluate the energy upgrading interventions in social housing areas, built in the capital of Greece, Athens. For this purpose, energy audits are performed in social housing in three different neighborhoods, in order to find the current building stock and later suggest energy upgrading solutions. The study is followed by a questionnaire survey to citizens of the neighborhoods under study. The majority of respondents consider significantly beneficial the energy-saving upgrade programs that the Greek Government has run in recent years, as they demand to be easier for everyone to participate. At the same time, respondents seem to be positive for future energy upgrade interventions, such as external insulation, frame replacement and implementation of renewable energy systems. Through the implementation of energy upgrade scenarios in the official national software for energy audits (TEE KENAK), results show that dwellings can upgrade up to 7 energy categories, with short payback time, reducing CO_2 and primary energy emissions.

1 Introduction

Climate change is one of the most important environmental problems, both nationally and globally. Its mitigation requires efforts by climate policymakers and the scientific community to find measures and solutions adapted to today's reality [1, 2]. With the majority of houses in Greece built before 1980, large amounts of energy are required in order to ensure thermal comfort conditions for the occupants. This reality has many negative effects on the economy, as citizens need enough money to maintain their households, while the country's energy load has been burdened [3]. Building stock and sociodemographic characteristics are strongly correlated, as Greek residential sector corresponds high amounts of energy use [4].

Recent studies show that Greek building stock includes materials with high embodied energy, which contribute to high consumptions [5]. Most buildings have outdated materials and systems, most of which include wooden single frames, central heating systems and energy-intensive domestic hot water (DHW) supply systems [6]. The buildings constructed for social housing constitute a small percentage of the total Greek building stock. Researchers have focused on finding the building stock of social housing, in order to propose sustainable energy upgrading solutions, in the disconnected areas of social housing, taking into account the owners' point of view on these solutions [7 - 9].

Other EU countries such as Italy have a similar building stock to Greece in the building ranking, as most buildings are without insulation, with low thermal coefficients and old central heating systems. The main difference is that in Italy there is a large proportion of social housing buildings, which seem to be responsible for the country's overall ranking given their age [10]. In contrast, in Nordic countries such as Norway and Sweden, significant developments in energy saving are taking place and thus residences rank high compared to the rest of the EU [11]. In the Netherlands, efforts are already being made for energy upgrading in social buildings, in almost zero-energy buildings, taking into account the citizens' point of view [12, 13]. Consequently, solutions that have been proposed, such as demolishing old buildings and constructing new ones, are proven to be no more efficient than energy upgrading existing buildings, as construction has significant environmental impacts and high costs, while energy upgrading can provide multiple benefits to the economy, energy consumption, human behavior and the environment [10, 14].

Energy upgrading interventions can be applied to the outer shell. External wall thermal insulation and replacement of frames are the most common solutions, due to low cost and great energy savings. Further solutions, such as the replacement of heating and air conditioning systems with heat pumps, split type air conditioners and the application of photovoltaic systems, further improve the overall efficiency, saving large amounts of energy. In a country with a high solar potential like Greece, researches emphasize the necessity of applying solar systems for DHW, which have the possibility of upgrading a typical house by at least 3 energy categories in the energy performance certificates [15]. Accordingly, systems such as automation in electromechanical equipment, upgrades in lighting systems and the integration of functions with smart systems (smart home), further increase energy savings. On the other hand, systems such as urban wind turbines are a viable alternative to meet energy requirements, as citizens in Greece tend to support renewable energy investments produced from natural sources [16].

The present study examines the building stock of dwellings built in social areas, proposing energy upgrading interventions from the existing literature. At the same time, the research includes a questionnaire survey from residents of the social housing areas, in order to take into account their opinion on future upgrading practices.

2 Literature review

2.1 Interventions in social housing areas in Greece

In Greece there is a limited amount of research on the current building stock, in social housing areas.

Bikas et al. [7] presented a case study for a project called Phoenix, which aimed at the renovation and energy upgrade of social housing in the area of Thessaloniki, through scenarios proposed by the students of the School of Architecture of the Aristotle University. The main goal, in addition to the upgrading of the building stock, was the upgrading of the Phoinika area, so that it becomes a sustainable suburb of Thessaloniki and is functionally integrated into the rest of the city. The measures that will be proposed related to the application of modern technologies, so that Phoenix becomes a new recreation area, while special emphasis was given to the renovation of social housing buildings. Solutions included installing trombe solar walls on the outer shell, solar panels for DHW, cogeneration systems for heating, cooling and electricity, as well as photovoltaic panels and solar areas on the roofs. The scenarios lead to great energy savings, as the solutions aim to improve the microclimate conditions and aesthetic upgrade of the social housing area [7].

Synnefa et al. [9] evaluated the energy upgrading process of a seven-story social apartment building located in Athens. Through the framework of a European Research Program known as HERB, a holistic analysis was developed in order to define and implement intervention scenarios aimed at promoting energy sustainable solutions. The optimal energy upgrade plan included replacement of double-glazed aluminum frames, external wall insulation, installation of night ventilation and ceiling fans, photovoltaic panels and an energy-efficient lighting system developed under the HERB program. After simulations, it was estimated that the energy savings can reach up to 80.3% and the corresponding CO_2 emission savings can exceed the initial goal of 60% [9].

Politis & Andreou [17], focused on the energy upgrade of a ten-story social housing building located in the Peristeri area, in Athens. The building was constructed in the 1970s and thus does not have adequate insulation on its outer shell. With that being said, the authors emphasize that the building is a representative example of the Greek building stock. The initial scenarios included external thermal insulation, installation of solar collectors and replacement of the existing heating system with heat pumps. The authors created energy efficiency measures that compose 15 different upgrade scenarios, with a gradual increase in the intensity of the measures and the corresponding economic and technical components. The scenario chosen by the residents of the building was the one with the lowest cost, with an initial investment capital of €7,000 per apartment and energy savings of 60%. The necessity of finding alternative ways of financing is emphasized, in order to eliminate the obstacles to the implementation of the above scenarios and the corresponding future ones [17].

2.2 Interventions in social housing areas in EU countries

Turri et al [18], analyzed a social housing complex in the city of Pavia, Italy. The buildings of the complex were built in 1956, have four floors and two apartments per floor. The proposed scenarios included external wall insulation, roof insulation, frame replacement, ground floor insulation and replacement of existing heating systems. The scenarios showed that buildings in the lowest energy categories can be significantly upgraded and have a total reduction in their annual consumption of up to 81% [18].

Guerra-Santin et al. [13] conducted a case study on the energy upgrade of a social housing building, to a near zero energy building, taking into account the occupants' behaviour during the design phase and during the implementation phase. The proposed solution was called Second Skin, because it upgraded the outer shell, as a comprehensive energy renovation strategy. In a second stage, a survey was conducted among the tenants, in order to evaluate the existing energy situation of their residence. The results were used based on simulations of the Second Skin solution, to find the final energy demand and consumption, after its implementation. The analysis showed that households tend to use up to 70% less energy depending on the type of household, while there are significant alterations in energy use between different households [13].

Finally, a study by the Norwegian Directorate of Cultural Heritage investigated the net environmental benefit of upgrades to a historic Norwegian house, taking into account energy use, material consumption and the life cycle of the building [14]. The study was carried out comparatively through two scenarios. The first involved the demolition and construction of an almost zero-energy building, while the second involved an energy upgrade with scenarios, such as installation of a heat pump, external thermal insulation and replacement of frames. The results of the simulations showed that the upgrade is particularly effective in mitigating the effects of climate change and particularly through the reduction of greenhouse gases, while with the construction of a new building it takes at least 50 years to recover the total environmental footprint [14].

3 Materials and methods

The methodology followed in this paper aims at the overall assessment of the energy behaviour of representative buildings, of different typologies, with an emphasis on social housing areas. The buildings are selected from the same climate zone, but from different construction times. In the first phase, their energy behaviour can be found, and in a later phase the most representative upgrade solution, with low implementation cost and payback time. In combination with the above, solutions are proposed, regarding the optimization of the microclimate, taking into account the opinion of the citizens. A questionnaire survey has been conducted in social housing areas in order to collect data on the actual situation and future practices that could be implemented.

Initially, an autopsy is performed in buildings in social housing areas in Athens. During the autopsy, the existing external shell of the building and the electromechanical installations are examined, in order to calculate the energy consumption, through the official national software of energy audits, TEE KENAK. Second, questionnaires are distributed to citizens of social housing areas. Most of the research is done through the door to door method, while online research is also carried out, in social media teams and groups of citizens. The first method is widely used in the global literature, because it allows the collection of data from the elderly, children, people without internet access, unlike the second [19, 30]. Finally, the data are analyzed, through the SPSS program, in order to perform statistical processing, extract Tables, graphs and further analysis and grouping of the results [31].

4 Results and discussion

4.1 Current status of social housing buildings in Athens

The settlement Nea Filadelfia I was created by the Workers' Housing Organization (OEK), after an extension of the current city plan, in 1955. In this region, almost 560 houses were built according to the current regulations, until the late 1977. During the construction, there was no provision for electromechanical equipment, especially for heating and air conditioning, because it was not mandatory to submit the corresponding studies to the city planning committee [20]. In this way houses today have systems installed by the owners at a later time in order to meet the energy demands of the households. In this settlement, an on-site autopsy and energy audit was performed, in a two-story single-family house that was built when the settlement was created. The house has no exterior shell insulation, metal frames with single glass panels, 1 air conditioning unit of 9000 btu/h for heating and cooling, while the DHW is supplied by an electric heater. Taking into account the current Greek regulations, an energy audit was carried out through the TEE KENAK program. The residence is classified in the lowest energy category (H), with total primary energy consumption per final use of 586.3 kWh/m^2 and total CO_2 emissions of 202.0 kg/m^2.

The settlement of Kato Kifisia I was created by the same organization (OEK), in the period 1968 to 1977 and after successive modifications of the local plan. The settlement, as preserved to this day, has 884 apartments in four-story buildings. In the houses of the settlement, no care was given to the preparation of electromechanical studies, which is why several houses to this day do not have the corresponding facilities. In the settlement of Kifisia, an autopsy was performed on a first floor apartment building, built in 1977. The apartment has metal frames with single panels of glass, no insulation on the exterior walls, while heating and cooling are provided by two 9000 btu/h air conditioning units. After calculations through the TEE KENAK program, the apartment is classified in the second lowest energy category (Z) with total primary energy consumption per end use of 217.2 kWh/m^2 and total CO_2 emissions of 74.1 kg/m^2.

The Kalogreza refugee settlement in Nea Ionia was one of the oldest refugee settlements created during the interwar period, through the assistance of the Refugee Rehabilitation Committee and the Ministry of Social Welfare, with the aim of immediately housing to refugees from Asia Minor [21]. Most of the refugee houses that survive today were built from 1940 onwards and take various forms. The most common form concerns single-storey houses made of stonework on the external walls, optical bricks on the internal and covered by a tiled roof with wooden slats or a reinforced concrete slab [22]. In the residences of the settlement no care was given to electromechanical systems, or any further study that was mandatory during construction. In this settlement, an autopsy was performed on a single-family house built in the 1950s. The external shell is made of stonework and partly of reinforced concrete, with optical brick infill, while the roof is of reinforced concrete. The exterior windows are double glazed in a metal frame which replaced the original windows in the 2000s. Heating is provided by gas central heating, with an integrated boiler system for DHW, while cooling is provided by a 9000 btu/h air conditioning unit. Through the TEE KENAK calculation program, it emerged that the building is in the second lowest energy category (Z), with total primary energy consumption per end use of 385.1 kWh/m^2 and total CO_2 emissions of 85.7 kg/m^2.

4.2 Questionnaire analysis

The questionnaire is formed into six different sections, which include 49 questions. The first part (Q1-Q9) consists of nine Likert type questions and focuses on a better understanding of the respondents' environmental consciousness, based on related criteria to their environmental behavior [28]. The second (Q10-Q18) consists of nine questions, of which four are Likert scale and five are multiple choice, as it aims to investigate the current energy situation of the respondents' residence. The third part (Q19-Q23) consists of five questions, of which three are of the Likert scale and two are multiple and predetermined questions. This section is about residents' willingness to participate in energy-upgrading initiatives using their own money or through government resources. The fourth part (Q24-Q27) consists of four questions, which are Likert scale, except the last one which is multiple choices. The fifth part (Q28-Q33) consists of four Likert scale questions and two open ended questions and concerns the existing situation in the neighbourhood as future possibilities are shaped in the context of a bioclimatic upgrade. The sixth part (Q34-Q49) concerns the socio demographic characteristics of the respondents and consists of twelve multiple choice questions and four open answer questions.

4.2.1 Socio-Demographic characteristics of the sample

The socio-demographic characteristics of the present sample and the sample from the last national census of 2011 by Hellenic Statistical Authority [24], are presented in Table 1.

4.2.2 Descriptive analysis

First, nominal variables are transformed into binary, so as to limit statistical analysis. The questions analysed in the first stage were those of the Likert scale, in order to find the correlation between the characteristics of the sample and each question. Correlation with quantitative variables where bivariate analysis was used was performed through Pearson's parametric correlation coefficient [23].

Table 1. Socio-demographic profiles of the responders, by frequency distribution.

Variables	Value	% (Sample)	% (Census 2011)
Gender	Male	48,3%	47,7%
	Female	52,7%	52,3%
Age	18-24	20,0%	10,9%
	25-39	15,0%	26,3%
	40-54	26,7%	26,6%
	55-64	15,8%	15,0%
	>65	22,5%	21,2%
Marital status	Single	11,70%	21,7%
	Married	21,70%	11,7%
	Divorced	66,70%	66,7%
	Widowed	0,00%	7,1%
Number of children	0	36,70%	36,6%
	1	25,00%	17,9%
	2	32,50%	35,6%
	3	5,80%	7,7%
Professional Status	Employment seeker	8,30%	8,90%
	Employee	77,50%	48,00%
	Pensioners	11,70%	23,80%
	Students	2,50%	19,30%
Education	Master & Phd holders	27,50%	4,70%
	Undergraduate & Univeristy graduates	61,70%	37,20%
	Elementary & High School graduates	13,00%	58,1
Total Family Annual Income	<20.000€	53,30%	
	20.001€-40.000€	37,50%	
	40.001€-60.000€	7,50%	
	80.001€-100.000€	1,70%	

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Findings show that men use more energy-saving practices, are happier when energy-saving interventions are implemented, and express a need to participate in government subsidy programs. Married people, adopt more energy-saving practices, prefer the implementation of interventions on the external shell of the building and have the need to participate in government subsidy programs. People with children are also interested in energy- efficiency practices, with an emphasis on solar and heating systems. Employees, state that they would participate in a subsidy program if they received advice from professionals. On the other hand, the unemployed and retired, feel the need for immediate energy upgrade interventions in their dwellings. University graduates express the same needs for energy upgrading practices, with government assistance. People over the age of 55, show a greater interest in information and implementation of practices, compared to the rest of the age group.

Furthermore, a statistical analysis has been conducted, with the method of principal components, also known as Principle Component Analysis (PCA). This method creates linear combinations from the variables analyzed in a previous step, so that there is a set of new correlated variables [25, 4]. By applying the PCA method, occurred that the Kaiser–Meyer–Olkin (KMO) index is 0.747, while the p-value in the Bartlett's sphericity test is 0.000, defining the sample as satisfactory for further analysis. The total variances of the selected questions and the generated models of the PCA method are presented in Table 2. For the analyzed questions, five different factors emerge in the model under consideration, which have a cumulative amount in the total variation of 70.86%, i.e. more than 50% that is the maximum preferred [25].

Table 2. Total variance explained for the selected questions.

Total Variance Explained			
Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	4,269	28,458	28,458
2	2,465	16,436	44,894
3	1,512	10,080	54,974
4	1,241	8,272	63,246
5	1,141	7,610	**70,856**

Furthermore, five different factors – components are extracted from the questionnaire, as shown in Table 3. The 1st factor shows a high loading value in the 3rd variable with 0.963, the 2nd in the 13th variable with 0.887, the 3rd in the 1st variable with 0.750, the 4th in the 9th variable with 0.834 and the 2nd in the second variable with 0.895.

Table 3. Rotated Component Matrix for the selected questions.

Rotated Component Matrix					
	Component				
	1	**2**	**3**	**4**	**5**
Q7			**,750**		
Q8					**,895**
Q14.1	**,963**				
Q14.2	,922				
Q14.3	,882				
Q14.4	,950				
Q14.5	,810				
Q19				,512	,463
Q20				**,834**	
Q25.1			,630		
Q25.2		,688			
Q25.3		,876			
Q25.4		**,887**	,501		
Q30		,482	,610		
Q31			,551		

Q7. State helps the owners with home energy upgrade programs.
Q8. I am satisfied with the energy efficiency of my home.
Q14. If you participated in a government subsidy program, which of the following and to what extent motivated you to participate?
- Q14.1. Possibilities to save energy
- Q14.2. Environmental consciousness
- Q 14.3. High financial subsidy
- Q 14.4. New system technologies
- Q 14.5. Friends / Acquaintances who had already joined

Q19. In the future, would you be interested in participating in a government subsidy program to upgrade your home?
Q20. In the case of not participating in a government subsidy program, would you be interested in upgrading your home energy-efficiently with equity?
Q25. Which of the following agencies and to what extent do you think would offer you the appropriate advisory support, in case of participation in an energy upgrade program?
- Q25.1. Engineer / project consultant
- Q25.2. Program body
- Q25.3. Familiar Municipality
- Q25.4. Ministry of Environment and Energy

Q30. Do you think that the municipality could contribute to the examination of the problems you face in the neighborhood?
Q31. Could citizens themselves contribute to looking at the problems you face in the neighborhood?

The **first factor** expresses the need to participate in government subsidy programs, with a greater effect on the possibility of energy savings and less on the influence of people from the familiar environment of the respondents who had already joined such a program. The **second factor** concerns the agencies that support citizens through counseling, in case they participate in state subsidy programs, where they are more influenced by the counseling offered by the Ministry of Environment and Energy and less by the program body. The **third factor** concerns the factors that contribute to the implementation of energy upgrading interventions in residential buildings and their neighborhoods. More specifically, there is an increased effect on assistance offered by the state through government subsidy programs, while there is a decreased effect on assistance offered by citizens to upgrade the neighborhood. The **fourth factor** demonstrates the necessity of energy upgrading practices, in the current building stock and the feasibility of using equity in the case of a non-government subsidy. The interest in energy upgrading has a greater influence on this factor even in case of not-participating a government subsidy program with equity capital and less influencing the interest in whether they will manage to join a government subsidy program to upgrade their home in future. The **fifth factor** expresses a greater effect on satisfaction with the existing energy efficiency of the respondents' building stock and a smaller effect on future upgrading practices that could be implemented without subsidy funds.

The K-means method finds clusters by randomly selecting data points as their initial centers and then by recording each point of the same datum for its center, given the average of the points given and assigned during the calculation progress [26]. In this paper, the components obtained by the PCA method and which had the strongest effect, are used, so that the indicators of each question are in function and uniformity [27]. First, the reliability index of the components is analyzed; with the goal that the values have an index greater than 0.65 and thus the analysis proceeds. The cluster centers are then calculated for each individual component, per part of the questionnaire. In the current study, the reliability index (Cronbach's Alpha) appears greater than 0.65, as described in Table 4, which means that if one of the above components is deleted, then the results will vary and the analysis will not be as representative.

Table 4. Item-Total Statistics for the selected questions.

Item-Total Statistics				
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
1	7,2917	7,855	,142	,737
2	7,1750	7,860	,136	,738
3	7,4833	6,907	,640	,680
4	7,4833	6,975	,607	,684

5	7,5167	6,958	,662	,680
6	7,5000	7,109	,560	,690
7	7,5667	7,491	,459	,703
8	6,8250	7,961	,236	,723
9	7,1250	8,278	-,010	,755
10	6,8167	8,218	,100	,733
11	6,9333	7,525	,345	,713
12	7,2250	7,235	,373	,709
13	7,1333	7,175	,403	,705
14	6,8000	8,010	,244	,722
15	7,0417	7,586	,262	,722

The centers of each cluster grouped, as shown in Table 5 and figure 1, are divided into two clusters.

Table 5. Final Cluster Centers for selected questions.

	Final Cluster Centers	
	Cluster	
	1	2
1	,48546	-,19990
2	-,64030	,26365
3	,48574	-,20001
4	,43765	-,18021
5	-,49427	,20352

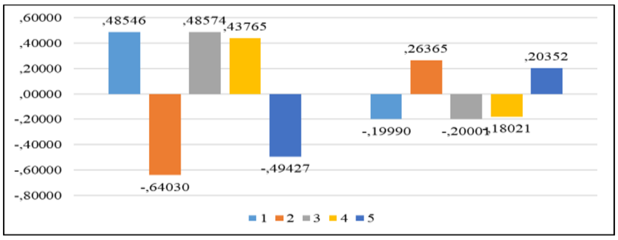

Fig. 1. Final Cluster Centers for selected questions.

In the **first cluster** the respondents in the past participated in a government subsidy program (25.9% of the sample), because they took into account the high energy saving potential. The same group includes respondents who believe that the government helps them with various energy upgrade programs (25.9% of the sample) and respondents who would upgrade their homes with their own money, if they did not participate in a government subsidy program (23.3% of the sample). In the **second cluster**, respondents consider that the Ministry of Environment and Energy should provide the proper guidance in case of participation in a state subsidy program (14.1% of the sample). The same group includes respondents who are happy with the current energy performance of their homes (10.8% of the sample).

Finally, as shown in Table 6, people who are in favor of energy upgrades have participated in a government subsidy program in the past and are positive about future practices in their homes, either through government subsidies or paying for them themselves. On the other hand, people opposed to upgrading techniques would prefer to receive advice from the Ministry of Environment and Energy if they participated in a government subsidy program, while feeling satisfied with their home's energy efficiency.

Table 6. Final clusters for new variables.

New factors	Clusters	
	1	2
	In favor for energy upgrades	Against energy upgrades
Participation in a government subsidy program in the past	,48546	-,19990
Counseling by the Ministry of the Environment in case of participation in a subsidy program	-,64030	,26365
Upgrading through government subsidy	,48574	-,20001
Energy upgrade through own funds	,43765	-,18021
Satisfaction with existing home energy efficiency	-,49427	,20352
Number of responses	**89**	**31**
Percentage (%)	**75,1%**	**24,9%**

4.3 Energy upgrades scenarios

Taking into account the literature review and the questionnaire research, scenarios are formed in order to upgrade efficiently with sustainable interventions and low initial cost, of the previously mentioned social housing, through the TEE KENAK program. Exterior wall insulation, frame replacement, new heating and DHW systems, and solar systems are the most popular energy improvement practices chosen by when asked: "*Which of the following interventions would you be interested in if you received a subsidy for the energy upgrade of your house?*".

The social housing building of the Nea Filadelfia I settlement results in a total cost of €27,854.0, after the implementation of energy saving interventions that upgrade the residence by 6 energy classes. The total primary energy consumption per end use is 71.4 kWh/m^2 and the total CO_2 emissions are 24.6 kg/m^2. In this way, a total annual primary energy saving of 514.9 kWh/m^2, i.e. 87.8%, a reduction in CO_2 emissions of 175.8 kg/m^2 is achieved and thus the residence is considered sustainable and more energy efficient. The cost concerns €365.92/m^2 for external wall insulation, roof thermal insulation, energy frames (windows), exterior doors, covers on the frames, one heat pump that includes an integrated DHW system, one air condition unit, automation integration and smart home functions. The average payback time for the above interventionsis 11 years, while the energy saving price is 0.6€/kWh.

In the social housing building of Kato Kifisia I, a total cost of €28,970.0 arises, after the implementation of energy saving interventions that upgrade the residence by 7 energy categories. The total primary energy consumption per end use is 20.1 kWh/m^2 and the total CO_2 emissions are 6.9 kg/m^2. There is a total annual primary energy saving of 197.1 kWh/m^2, i.e. 90.8%, a reduction in CO_2 emissions of 67.2 kg/m_2 is achieved and thus the house is more energy efficient. The cost concerns of €342.84/m^2 for external wall insulation, energy efficient frames (windows), exterior doors, covers to the frames, one heat pump that includes an integrated DHW system, three air condition units, automation in the heating system, a solar collector and smart-home functions. The average payback time is 16 years, while energy saving price is 1.5€/kWh.

In the single-family house of the Kalogreza settlement, a total cost of €21,565.0 results from upgrading the residence by 6 energy categories. The total primary energy consumption per end use is 50.2 kWh/m^2 and the total CO_2 emissions 41.3 kg/m^2. Therefore, a total annual primary energy saving of 334.9 kWh/m^2 i.e. 87.0% and a reduction in CO_2 emissions of 74.6 kg/m^2 is achieved creating a more efficient home. The cost concerns of €285.36/m^2 for external wall insulation, roof thermal insulation, energy efficient frames (windows), external doors, covers on the frames, two air condition units, a solar collector and smart-home functions. The average payback time for the interventions is 14.5 years, while the energy saving price is €0.9€/kWh.

Finally, improvements in vehicular and pedestrian traffic, as well as tree planting, are the main objective of bioclimatic planning interventions. Another type of intervention that could be implemented is to increase the albedo effect in all buildings, replace pavement slabs with cool materials and the greening of empty building blocks [29]. In this way, by reducing the outside temperatures, especially in the summer months, the internal-climate of social and non-social buildings is significantly improved.

5 Conclusions

The on-site autopsy, in the settlements of OEK Nea Filadelfia I, Kato Kifisia I and the refugee settlement of Kalogreza in Nea Ionia, investigated single-family houses and multi-family houses. The common features in all three different buildings were the lack of insulation and electromechanical systems during the construction times, which determined them in the lowest energy categories, throughout energy inspections, with the TEE KENAK program. Accordingly, the settlements were shown to have major deficiencies in infrastructure and green spaces, as they were built on existing blocks in urban areas.

The questionnaire research conducted in the same social housing areas found similar socio – demographic characteristics to the last national census in 2011, with 120 responses. The results show that men use more energy-saving practices, feel more satisfied with the implementation of energy-saving solutions, and feel the need to participate in government subsidy programs. Married people adopt more energy management practices, prefer implementing interventions on the outer shell and have the need to participate in subsidy programs. Those with children are interested in corresponding energy upgrading practices, while working responders would participate in a subsidy program if they received advice from professionals. People over 55 show more interest in information and implementation of practices than the rest of the age group.

In addition, PCA analysis defined five factors, of which K-means analysis defined two clusters. The first cluster defined the responders who participated in a state subsidy program because they took into account the high energy saving potential, it also includes those who consider that the state significantly helps citizens in the various energy upgrading programs, as well as respondents who would upgrade homes with their own money, in case of non-participation in a government subsidy program. The second cluster includes respondents who believe that appropriate counselling in case of participation in a state subsidy program, should be provided by the Ministry of Environment and Energy and respondents who are satisfied to some extent with the existing energy performance of their dwellings. The final findings show that those who support energy upgrades have previously participated in government subsidy programs and are in favour of future energy upgrade practices in their homes, whether those upgrades are done through a government subsidy program or using equity. On the contrary, people opposed to upgrading practices would prefer to receive advice from the Ministry of Environment and Energy if they choose to participate in a program in the future, while feeling satisfied with their current energy efficiency.

Finally, energy upgrade scenarios are proposed, using existing literature and survey results. After energy-saving interventions, such as external wall insulation, energy frames (windows and doors), window coverings, heat pump with DHW system, air-conditioning systems and solar systems, the social housing of the Nea Filadelfia settlement is being upgraded at a total cost of €27,854.0 by 6 energy categories, the Kato Kifisia social housing is upgraded at a total cost of €28,970.0 by 7 energy categories, while the single-family house Kalogreza is upgraded by six energy categories, at a total cost of €21,565.0. The overall results show that payback times are under 15 years, with energy price savings between 0.6€/kWh to 1.5€/kWh, and total annual primary energy savings of up to 90,8%, reducing overall CO_2 emissions.

Limitations of this study are the low response to the questionnaire research received and the few social housing buildings analyzed. Future research can be conducted in social housing buildings, both from Greece and other EU nations, in order to broaden the current results. Additionally, it would be necessary to conduct an additional analysis in other social housing settlements, which are located in different climate zones and consist of the same building typologies. Finally, with the contribution of the state, the questionnaire research could be carried out by with a larger sample. Overall, in-depth investigation of public awareness of the current building stock and future solutions can help the global movement for energy efficient households, especially in social areas.

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