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Socioeconomic Factors Driving the Transition to a Low-Carbon Energy System

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Abstract: Citizen participation via different investment schemes may be a promising solution to the financing barriers inhibiting energy transition. In this regard, citizens may be approached as potential investors in renewables, but, to mobilize their capital, strategies need to be developed. Much like other services or products seeking to improve their market position, renewable energy investments by citizens also require dedicated efforts to acquire a strong market position. Using a large sample of Greek citizens, this study investigated whether it is possible to identify distinct and addressable citizen clusters which can enable energy developers and marketers to effectively address the preferences and needs of potential investor segments. The performance of k-means cluster analysis identified four clusters: Indifferent Investors were neither driven by economic or social factors, Enthusiastic Investors were motivated both by economic and social factors, Pro-environmental Investors were driven by the environmental benefits, and Social Investors were motivated by the social aspects of the investment. Moreover, each cluster demonstrated different levels of willingness-to-invest in renewable energy and were knowledge about renewable energy investments. It was concluded that citizens should not be approached as a homogeneous target group by marketing experts and policymakers, while novel strategies should be followed.

Keywords: energy transition; renewable energy; socioeconomic drivers; citizen investment; cluster analysis; attitudes to renewable energy

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1. Introduction

The European Union (EU) is widely recognized as a leader in renewable energy due to its continuous policy efforts to increase the penetration of renewable energy sources (RES) in member states' energy mixes. The energy policy of the EU is characterized by setting increasingly ambitious targets, and more recently, it has set an EU-wide emission reduction target of a minimum 55% net emissions by year 2030 as part of the "FiT for 55" package [1]. The outcome of these efforts seems more critical than ever given the recent energy crisis due to the armed conflicts around the globe. As future development is at risk, the deployment of renewable energy sources is a necessary step for the continent. As an EU member state, Greece presents an interesting case for the study of energy transition because it has introduced a multitude of regulations and policies to promote the penetration of renewable energy in its energy mix, and at the same time, it possesses a remarkable renewable potential [2,3]. The country exerts great efforts to lower its greenhouse gas emissions and, according to the latest national report, greenhouse gas emissions (without measuring the levels of LULUCF) amounted to 77.50 Mt CO_2 eq in 2021, showing a notable decrease of 25.48% compared to reference year 1990, in which the emissions were equal to 101.74 Mt CO_2 eq (including all emissions sources) [4,5]. To contextualize the latter, the corresponding emission reduction rate achieved across EU was 30% [6]. The impressive decrease achieved by Greece can be ascribed, to a significant extent, to the policy efforts to increase the installed capacity of renewables. More recently, Greece has revised its

National Energy and Climate Plan and has set even more ambitious national targets to be met by 2030 compared to EU-wide targets [7]. The new targets involve a minimum of a 35% percentage of renewable energy in the final gross energy consumption, a 42% decrease in greenhouse gas emissions compared to 1990 levels, and an at least 38% rate of energy efficiency in final energy consumption. Moreover, the Greek parliament has also passed the Climate Law, which proposes additional mitigation measures, such as higher penetration of electric vehicles (EVs) [8]. The country has also been implementing a highly radical lignite phase-out schedule, which aims at the total decommissioning of all lignite plants. Despite these efforts and the progress towards emission reduction targets, the country still needs increase the install capacities of renewables. Yet, the transition to a renewable-based energy system is facing significant cost barriers, and attention is required to closing investment gaps because public finance alone cannot suffice to ensure continuous progress towards the decarbonization of the energy sector [9,10].

As alternative financing concepts are required, investments in renewable energy sources can be a straightforward way for citizens to participate in energy transition [11–14]. Citizens now have the option to participate in different investment schemes and, in this way, to provide a considerable part of the capital necessary for the deployment of renewable energy [15]. In many EU countries, citizens have made substantial investments in renewable energy, thereby contributing to their country's energy transition by allocating financial resources to energy policy implementation [16]. It is important to note, however, that in these countries, there were established mechanisms for citizen investment in renewables [17].

The promising role of citizens in financing energy transition brings forward the need to conduct more research to understand the intricacies of citizen decision-making. So far, many studies on the subject have focused on the sociodemographic, financial, and non-financial variables that affect investment decisions [11–14]. From a broader perspective, it has been observed that all investments, including those made by citizens, are resulting from rational and well-calculated decision-making. In this regard, marketers and energy developers should not be surprised that citizens tend to express rational and well-rounded preferences for renewable energy investments and, most notably, for return on investment [18,19]. Moreover, citizens, as potential RES investors, have been found to prefer investments where the certainty of financial returns is considerable [20,21]. Return on investment has also been found to be more influential to citizens' investment decision compared to the estimated investment depreciation [20].

In addition to the factors described above, other economic factors that have a positive effect on investment decisions involve incentives, such as subsidies, tax credits, and financing aid for house improvements (in cases where the incentives are intended to induce investments in solar energy). More analytically, Vasseur and Kemp [15] indicated that incentives, along with aid for house improvements, act as strong motives for citizens to invest in residential photovoltaic systems. Conversely, the risk of the investment can act as an inhibiting factor for citizens that are principally interested in the certainty of the investment [21]. At the same time, citizens express an acute aversion to long-term investments, and it is due to this aversion that citizens feel more comfortable to invest along with energy communities or public electricity companies [21]. A recent study has confirmed that citizens as investors are very sensitive to the risk of losing the entire investment [22].

Another critical economic factor in citizens' decision-making is the cost of the investment, which, if deemed too high, acts as a barrier per se to investments in renewables [23]. The study by Vasseur and Kemp [15] indicated that the investment cost was seen as the primary obstacle to investing by the majority of respondents. In addition, around half of respondents in the same study thought that the cost must be significantly reduced for them to invest, and many of them would invest only under a highly attractive subsidy scheme [15]. The crucial role of cost in investment decision-making also accounts for high-incomers' higher willingness to invest compared to those with fewer financial resources [24], but it also places attention on the adverse influence of insufficient savings and restricted loan access on RES investment decisions [21]. In contrast to the cost, lower anticipated household electricity costs due to RES investment act as a strong motivation for householders, especially with regard to investments in residential renewable systems. In such cases, achieving electricity cost reductions through investments in RES seems to be a strategic choice for citizens with an excess of disposable income that try to ensure lower household expenses in the future [25].

In addition to the economic factors discussed above, citizens' investment decision is also affected by social factors. Specifically, individuals' perceptions about their role in society and their ability to influence other society members can be a motivating factor. Schelley [26] noticed that a considerable part of citizens who had adopted residential renewable systems viewed themselves as advocates for the feasibility of residential renewable systems and believed they should set an example within their community. At the same time, the social circle of potential investors is often a strong driver because if adopters are included in it, potential investors are able not only to become acquainted with new technologies and explore their feasibility, but also discuss their concerns [27]. In addition, individuals may also be persuaded to invest if community members that are viewed as significant by the community have invested or if the investment is highly valued by most community members [28]. The strong effect of community attitudes was recently corroborated by Knauf and le Maitre [29].

The technique of market segmentation may prove useful in providing a new angle of the role of socioeconomic factors in citizens' investment decisions, as it is a procedure in which the potential market is divided into distinct subsets of individuals who express the same needs, preferences, and priorities [15,30]. There are many advantages to this approach, and most importantly, it enables marketers to address the problem of consumer heterogeneity by segmenting them in order to identify and address different clusters. Marketers are also able to choose one or more clusters as a target market and reach them with the use of tailored marketing strategies and tools. To put this differently, this kind of approach enables marketers to capitalize on the preferences and needs of consumers in each cluster in order to enhance the probability of as many of them as possible choosing the product or service in question. The fundamental idea underlying market segmentation is that consumers are different, and thus one strategy cannot be effective for all of them [15,30].

Much like every kind of service or product that seeks to improve its position in the market, renewable energy investments can also be seen as a product that requires dedicated efforts in order to acquire a strong market position. To that end, it is necessary to better understand citizens' decision-making and try to segment them in order to develop strategies to mobilize their capital. Despite the potential benefits of citizen segmentation, there has so far been scant research efforts on developing citizen RES investor clusters. Of the existing research works, Vasseur and Kemp [15] conducted a web-based survey in 2011 on householders in the Netherlands and developed a segmentation model for technological innovations. The clusters were based on whether the adoption was voluntary or not, as well as on whether the household could be characterized as a potential adopter or rejecter. Petrovich et al. [31] examined Swiss homeowners' preferences for building retrofits and developed two clusters of potential solar adopters, with the 'premium' segment expressing preference for colored and building integrated solar systems, and the 'value' segment being more sensitive to the price of the systems. Another segmentation study was performed by Ebers, Broughel, and Hampl [32] in Austria and Switzerland, and focused on the socio-demographic and the socio-psychological characteristics of potential investors. This study managed to identify four clusters of potential investors based on their place of residence (urban and rural dwellers), as well as on their acceptance of wind energy projects in the vicinity of their residence. The groups were described as rural and urban wind energy enthusiasts and as urban and rural wind energy skeptics. More recently, Gáspár et al. [33] examined investment preferences based on sociodemographic characteristics, and identified a group preferring green investment aspects to financial returns and a group that can be affected by suitable marketing strategies.

Another stream of the literature has developed clusters of residents according to their willingness to participate in energy communities. Specifically, Wang et al. [34] classified residents in three clusters according to innovation diffusion groups in view of their attitude to participate in energy communities: Earlier Adopters, Mid-term Adopters, and Later Adopters. Heiskanen et al. [35] examined investor heterogeneity in Finland by focusing on investment drivers and available investment options, and identified investors whose investment was induced by profit seeking motives through the feed-in-tariff system and those investors who were mostly real estate owners and invested in heat pumps in order to benefit from the low interest rates.

It can be seen that numerous previous studies on citizen willingness-to-invest in renewable energy have primarily examined the economic and social factors affecting citizen decision to invest, while the true extent of this influence remains somewhat vague. That is, most studies have noted the role of socioeconomic factors, but very few of them have tried to examine whether and how economic in conjunction with social factors affect citizen decision-making. Moreover, most relevant studies often depend on datasets derived from small sample sizes, while much research focuses on citizens that have already invested in specific investment schemes rather than on non-investors whose willingness-to-invest is much more relevant to examine if we are to devise new strategies to mobilize citizen RES investment. Furthermore, the ability to classify citizens based on how they evaluate the effect of socioeconomic factors is underexplored, even though it may hold the potential to introduce a novel approach to policymaking design. There is thus a remarkable gap in the literature which is crucial to fill for various reasons. Understanding how citizens can be classified according to their evaluation of socioeconomic investment drivers is necessary in order to inform targeted interventions and support mechanisms. A precise idea of citizen decision-making may also be the missing link to designing investment mechanisms that correspond better to citizens' needs and preferences. It is, therefore, worthwhile to examine if such segmentation is possible because this may reveal novel nuances that may have been missed in marketing strategies and policies. In addition, as attitudes to renewables constantly change, it is necessary to conduct research regularly so that marketers and policymakers have a precise idea on the factors that affect citizen investment [27]. Using a large citizen sample that allows for a better differentiation among clusters, this study aims to investigate whether it is possible to identify distinct and addressable citizen clusters which can enable energy developers and marketers to effectively attract and address the preferences and needs of potential investor segments.

The remainder of this paper is structured as follows: The second Section describes in great detail the methods that were followed to carry out the study, and then, in the third Section, the developed clusters are presented. Afterward, the results reported in this paper are discussed, and in the last Section, conclusions are reached and study limitations are stated.

2. Research Methodology

2.1. Research Area

The analysis presented in this paper is part of a broad research that focused on citizens' attitudes towards renewable energy investments. The study area involved all households in Greece, a member state of the EU located in southeastern Europe. Greece was chosen as the study area because it has a notable renewable energy potential and, if energy transition is successfully implemented, the country can become a remarkable renewable energy producer in the EU [2,3].

2.2. Questionnaire Design and Sampling Method

The research was performed using a structured questionnaire which was constructed drawing on the literature on citizen investors' socioeconomic profile, motives, barriers, and preferences [11,15,18–21,23–25,32]. In addition, the design of the questionnaire took into account the policy framework in place for investments in renewables in the study area ensuring that investment parameters were considered in the content of the items. The questionnaire involved eight thematic sections gathering information about (i) respondents' perceptions of energy topics, (ii) their knowledge on RES investments, (iii) their willingness to invest, (iv) their evaluation of economic, environmental, and social factors affecting the investment decision, (v) their perceptions of barriers to RES investments, (vi) their satisfaction levels with various stakeholders' actions to enable RES investments, (vii) their environmental attitudes, and (viii) their sociodemographic characteristics. Results reported in this paper are based on the data from the fourth Section, which examines respondents' evaluation of factors affecting their decision to invest in renewables. It should be noted that all items were measured with a five-point Likert scales to enable a higher level of precision and a wide range of statistical analyses.

The efficacy and accuracy of the questionnaire was ensured by performing a pilot study on a limited sample of 30 Greek citizens from diverse socioeconomic backgrounds. In view of the results of the pilot study, some changes were made. Specifically, a few phrases in the items had to be reworded to ensure that they would be understood by respondents, the response scale for one item had to be changed to facilitate responses, and the order of three items was re-arranged to improve the coherence of the questionnaire and to avoid confusion among respondents. In accordance with Law 4521/2018 and, in particular, the provisions stated in Article 23, this research applied for and was granted a permit from the Research Ethics Committee of the Democritus University of Thrace (Decision No. 3/9 December 2019), the entity responsible for examining and approving every research conducted by researchers affiliated with the university.

To recruit respondents and to attain a representative citizen sample, the simple random sampling method was used [36]. Compared to other sampling methods, this method has also some distinct benefits, and most importantly, it does not require a very high level of knowledge about the population under study [37,38]. The population under study consisted of all households in Greece. It should be noted that the use of households is a classic case of utilizing a group of people as a sampling unit, while this method is significantly more convenient and affordable [39]. The process of choosing one member from each randomly selected household ensured that the same member would not be always chosen [36,39].

To calculate the sample size, the formula of simple random sampling (1) was used, and in particular, simple random sampling without replacement was employed. For this reason, the factor of finite population correction could be excluded, as the size of the sample (n) was somewhat 'limited' in comparison to the population size (N) [40]. According to our estimation, 1536 citizens had to participate in the study.

$$n = \frac{t^2 \cdot \bar{p} \cdot (1-\bar{p})}{e^2} = \frac{1.96^2 \cdot 0.50 \cdot (1-0.50)}{0.025^2} \cong 1536 \quad (1)$$

In this formula, t expresses the value of Student's t-distribution with $(1-\alpha)$ = 95.0%. In this calculation, $n-1$ degrees of freedom are used, while e expresses the level of precision (that is, the margin of error). Because the size of pre-sampling is somewhat large (greater than 50), the value of t is retrieved from standard normal distribution tables, and in this way, for a probability of 95%, the value is 1.96 [40]. In addition, the p-bar estimates the proportion, and e expresses the highest acceptable difference between the sampling mean and the mean of the unknown population. It may be accepted that it is 0.025, i.e., 2.5%.

Moreover, pre-sampling using a sample of 50 subjects had to be conducted in order to estimate the real proportion of the population for each variable. This was a necessary step because the questionnaire must be able to accurately calculate a substantial number of different variables. The variable 'Gender' was the one that gave the highest sample size, and when the calculated sample sizes are similar but may be afforded, then the highest sample size must be selected [40]. All questionnaires were filled in through personal interviews with the respondents in order to ensure that questionnaires were fully understood and completed. Finally, 1536 respondents participated in the study, and to ensure their anonymity, the questionnaires were placed in envelopes and were destroyed after data coding.

2.3. Data Processing

After questionnaire collection, the data were coded and entered into the Statistical Package for Social Sciences (SPSS, version 22). Prior to cluster analysis, factor analysis had to be performed to decrease the number of observed variables into fewer latent variables (factors) which would retain the most information of the initial dataset [41]. As for the significance of the principal components, we used the criterion proposed by Guttman and Kaiser, according to which, the limit for acquiring the necessary number of principal components is determined using the eigenvalues that are $\geq$1 [42,43]. The analysis was completed with a varimax rotation of the principal components to optimize results [44]. A factor analysis was used in this study to obtain the factors from the following multivariates: 'economic reasons for investing in renewable energy (Q7)' and 'social reasons for investing in renewable energy (Q9)'.

K-means cluster analysis was chosen for this study because it classifies observations into a predefined number of clusters (k), optimizing inter-cluster differences and minimizing intra-cluster variance on specified variables [45]. In addition, in the k-means method, the first observations can be reclassified into another cluster if it is a more suitable fit. This type of clustering provides a series of solutions which correspond to different numbers of clusters, that is, k-means [46]. In k-means clustering, the algorithm used for defining the contribution of observations is based on the closest classified centroid. An observation falls into the cluster which presents the smallest distance between the observation and the cluster centroid. If centroids are already known, they can be defined in the start. If, however, they are not known, they need to be estimated through an iteration process. The application of k-means clustering means that the classification of new observations into clusters is based on the proximity of each observation to these centers [45]. The center of each cluster is merely the numerical mean of all variables for the variables falling into the respective cluster. The initial values of the new observations are then standardized in z values, and afterward, the Euclidean distances from cluster centers are estimated. The observation falls into the cluster that presents the smallest distance [47].

Following the integration of new observations into clusters, the estimation of the clusters' real centers becomes feasible. These values are the final centers (centroids), which are slightly different from initial ones, especially in cases where the observations had not fallen into any cluster previously. The distances are able to indicate the degree of the differentiation among clusters, and this is achieved through the estimation of Euclidean distances for every two centers [47].

To build the citizen typology, a series of steps were followed. First, the variables to establish the typology had to be selected. The selected variables involved the economic and social factors affecting the respondents' decisions to invest in renewable energy. As this was a high number of variables, a factor analysis had to be performed in order to discover the relationships among the variables and underlying dimensions. Then, to identify the most appropriate number of clusters, various clustering combinations were examined. Afterwards, respondents were classified based on the selected criterion using cluster analysis and, finally, results were evaluated [46]. The description of citizen profiles also took into account respondents' demographic characteristics as well as investment-related variables. It is important to note that the chi-squared test was performed to verify that the clusters differ in terms of sociodemographic variables. Finally, a typology of citizens was established, and the types were named by the researchers in a way that reflected the citizens' characteristics in relation to their evaluation of socioeconomic factors related to RES investments.

3. Results

3.1. Sample Characteristics

In the sample, female respondents outnumbered (by 51.6%) their male counterparts, and with regard to age, most respondents were aged 41 to 50 years old (by 27.9%). With regard to occupation, the respondent percentages who reported being employed in the private (by 21.2%) and public (by 19.9%) sectors were considerably higher in comparison to the other occupations. Regarding education level, most respondents were university graduates (by 22.3%), as well as upper secondary school graduates (by 20.8%). Regarding respondents' family status, around half of them were married (by 51%), while a considerable percentage reported having two children (by 28.3%). Most respondents reported residing in urban centers (by 64.1%). As for their annual income, 28.5% of reported earning between EUR 10,001 and EUR 20,000, and 20.1% reported earning between 5001 and 10,000 Euros a year.

3.2. Profiling Citizens as Potential Investors in Renewable Energy

In order to investigate the underlying structure of respondents' views on the economic and social reasons for investing in renewable energy, a principal components analysis with Varimax rotation was carried out. Regarding the multivariate 'economic reasons for investing in renewable energy (Q7)', Cronbach's alpha value was equal to 0.883, the Keiser-Meyer-Olkin index scored 0.888, and a Bartlett's test of sphericity rejected the null hypothesis (Chi-Square = 5932.216, df = 6, $p < 0.001$). The analysis yielded two factors, 'Subsidies, low investment taxation and improved income and electricity cost (PC1_1)' and 'Optimal investment opportunity and protection from oil price fluctuations (PC1_2)' (Table 1).

Then, to examine the structure of responses for the multivariate 'social reasons for investing in renewable energy Q9', a principal components analysis with Varimax rotation was again performed. Cronbach's alpha value was 0.802, the Keiser-Meyer-Olkin index scored 0.712, and a Bartlett's test of sphericity rejected the null hypothesis (Chi-Square = 3283.840, df = 10, $p < 0.001$). The analysis gave two factors: 'Boosting social profile (PC2_1)' and 'Pro-environmental behavior and example (PC2_2)' (Table 1).

In order to identify the structure underlying citizens' views on the economic and social reasons for investing in renewable energy sources, second-order factor analysis was performed. Before the performance of the second-order factor analysis, the following necessary tests were carried out: the Keiser–Meyer–Olkin index had a value of 0.448, and Bartlett's sphericity test rejected the null hypothesis (Chi-Square = 350.703, df = 6, $p < 0.001$). The analysis gave two factors. The first factor (P1) is named 'Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost' and involves the variables 'Pro-environmental behavior and example (PC2_2)' and 'Subsidies, low investment taxation and improved income and electricity cost (PC1_1)'. The second factor (P2) is named 'Social profile, sound investment and independence from oil prices (P2)' and includes the variables Optimal investment opportunity and protection from oil price fluctuations (PC1_2)' and 'Boosting social profile (PC2_1)' (Table 2).

Table 1. Factor analysis results with varimax rotation of the reasons for investing in RES.

Principal Components—Variables Loaded in Each Factor	Loadings	Eigenvalue
Subsidies, low investment taxation, and improved income and electricity cost (PC1_1)		**4.664**
Income increase through selling produced energy	0.772	
High subsidies granted for RES investments	0.752	
Reduction in electricity costs	0.737	
Low taxation on RES investments	0.693	
Acquisition of stable income	0.600	

Table 1. *Cont.*

Principal Components—Variables Loaded in Each Factor	Loadings	Eigenvalue
Optimal investment opportunity and protection from oil price fluctuations (PC1_2)		**0.915**
The relatively low investment cost compared to other investment types (e.g., asset purchase)	0.811	
Short depreciation time	0.769	
Capital investment	0.690	
Protection from oil price fluctuations due to geopolitical crises	0.690	
Total variance (%): 61.995		
Keiser–Meyer–Olkin = 0.888, Bartlett χ^2 = 5932.216, df = 6, $p < 0.001$		
Boosting social profile (PC2_1)		2.828
Increasing respect from friends and acquaintances	0.895	
Social prestige through entrepreneurial activity	0.885	
Pro-environmental behavior and example (PC2_2)		1.032
The desire to adopt pro-environmental behavior	0.817	
The desire to set a good example for my family	0.785	
The desire to set a good example for society	0.759	
Total variance (%): 77.206		
Keiser–Meyer–Olkin = 0.712, Bartlett χ^2 = 3283.840, df = 10, $p < 0.001$		

Table 2. Factor loadings of the data after Varimax rotation for all reasons for investing in renewable energy.

Principal Components—Results of Second-Order Factor Analysis	Loadings	Eigenvalue	Variance (%)
Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost (P1)		1.452	36.292
Pro-environmental behavior and example (PC2_2)	0.816		
Subsidies, low investment taxation, and improved income and electricity cost (PC1_1)	0.653		
Social profile, sound investment and independence from oil prices (P2)		1.025	25.621
Optimal investment opportunity and protection from oil price fluctuations (PC1_2)	0.744		
Boosting social profile (PC2_1)	0.722		
Total variance (%): 61.913			
Kaiser–Meyer–Olkin = 0.448, Bartlett χ^2 = 350.703, df = 6, $p < 0.001$			

3.3. Description of Citizen Clusters

The application of k-means cluster analysis served to indicate the association of each member to the cluster. The ANOVA was performed to test if respondents can be clustered according to socioeconomic reasons for investing in renewable energy sources. Results pointed to the existence of important differences, and thus the proposed clustering could be accepted.

Two-, three-, and four-cluster solutions were explored using the k-means procedure, which was used in order to identify natural groupings of respondents based on their evaluation of socio-economic reasons to invest in renewable energy sources. The best solution was given by the solution of four-clusters, as it provided an optimal balance between within-cluster homogeneity and between-cluster heterogeneity.

Table 3 shows dimensions' average scores for the characterization of clusters. Cluster 1 can be labeled as 'Indifferent Investors' and represents only 9.4% of the sample (it is the smallest cluster). Its members were not affected positively by both factors, and when compared to the other clusters, this cluster stood out as giving the lowest importance to "Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost". The second cluster is the second largest cluster, as it represents 30.5% of the sample. This cluster can be named 'Enthusiastic Investors' because its members classify both factors positively. It is also the cluster that ascribed higher importance to the factor concerning "Social profile, sound investment and independence from oil prices". Cluster 3 can be designated as 'Pro-environmental Investors' and includes 28.9% of the sample. Its members attached greater value to factor 'Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost', but lesser value to 'Social profile, sound investment and independence from oil prices'. Finally, the fourth cluster can be labeled as 'Social Investors', and is the largest cluster (with a small difference from Clusters 2 and 3), including 31% of the sample. Members of this cluster are characterized by the higher level of importance they ascribed to 'Social profile, sound investment and independence from oil price fluctuations' and the lower importance they attributed to 'Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost'.

Table 3. Mean factor loadings of the four clusters.

	CL1 (9.4%) Indifferent Investors	CL2 (30.5%) Enthusiastic Investors	CL3 (28.9%) Pro-Environmental Investors	CL4 (31%) Social Investors	Cluster		Error		F	p-Value
					Mean Square	df	Mean Square	df		
(P1)	−2.10465	0.55281	0.54963	−0.41651	334.265	3	0.347	1532	962.208	0.000
(P2)	−0.13794	0.95132	−1.04727	0.08358	306.200	3	0.402	1532	761.028	0.000

The analysis of each cluster's profile is presented in Table 4. The analysis is based on statistical significant differences using chi-square tests between the four clusters. The clusters are thus described based on the level of differentiation that they entail and the overall positive or negative effect of the examined socioeconomic factors. More specifically, the analysis has indicated four clusters: 'Indifferent Investors', 'Enthusiastic Investors', 'Pro-environmental Investors', and 'Social Investors'.

Cluster 1 'Indifferent Investors':

Cluster 1 (smallest cluster), whose members were indifferent to socioeconomic reasons for investing in RES, consists of citizens who are likely to be public and private employees. Most are primary school and university graduates. In addition, most members in this cluster are married and earn between EUR 10,001 and EUR 20,000 per year. A high proportion from this cluster reported having little knowledge about investments in renewables, and was significantly less willing to invest compared to citizens in the other clusters.

Cluster 2 'Enthusiastic Investors':

Cluster 2 (second largest cluster) was labeled 'Enthusiastic Investors' because the members of this cluster classified socioeconomic factors positively, while higher importance was given to factor concerning "Social profile, sound investment and independence from oil prices". Members of this cluster are likely to be public and private employees, and compared to the other clusters, this one has the highest proportion of crop farmers. Most citizens are upper secondary school and university graduates. This cluster has also more vocational training school graduates compared to the other clusters. Much like the previous cluster, the majority is married and earns between EUR 10,001 and EUR 20,000. More than half citizens in this cluster reported knowing much and very much about renewable energy investments. This cluster reported significantly higher willingness to invest in renewables, and only as few as 10% from this cluster would not invest.

Cluster 3 'Pro-environmental Investors':

Citizens in Cluster 3, whose members attached greater value to the factor 'Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost', are likely to be public and private employees. Meanwhile, this cluster presents the highest percentages of pensioners and holders of Bachelor's and Master's degrees. Most citizens in this cluster are married and earn between EUR 10,001 and EUR 20,000 a year and have a moderate knowledge about RES investments. Citizens from this cluster would either invest lower sums of money (EUR 500–2000) or not invest at all.

Cluster 4 'Social Investors':

Cluster 4, the largest cluster, involves citizens characterized by the higher importance they ascribe to 'Social profile, sound investment and independence from oil prices' and the lower importance they attributed to 'Pro-environmentalism, favorable investment conditions and benefits for income and electricity cost'. Most citizens are private employees, while this cluster involves the highest number of unemployed citizens. Most members from this cluster have completed upper secondary school. This cluster has the lowest proportion of university graduates compared to the other clusters. Much like the other clusters, the highest percentage of citizens is married and earns between EUR 5001 and EUR 10,000. In addition, most citizens in this cluster have a moderate knowledge about investments in renewable energy sources. Finally, the majority would not invest in renewables or would invest between EUR 500 and EUR 1000.

4. Discussion

Citizen investment in renewable energy holds promising potential as an alternative means of financing energy transition [11–14]. As public financing may not suffice, citizens can become investors, thereby supplying a part of the necessary capital and contributing to significant energy targets. Much like any other investor group, citizens will proceed to investments only if they perceive the investment as one that is suitable for their own needs, expectations, and preferences [11,16]. Citizens are thus evolving into a new target investor group for which novel marketing approaches must be devised [20,21]. Our study sought to examine whether there is homogeneity in citizens in relation to investments in renewable energy, and indicates remarkable differences that raise several implications. As a consequence, marketing strategies and investment policies need to be tailored according to the differences observed among the four citizen segments.

This study classified citizens based on how they evaluated a set of economic and social factors in terms of their influence on the decision to invest in renewable energy. The segments that resulted from our analysis exhibited considerable heterogeneity, and it is important to observe that the four clusters demonstrated different levels of appreciation of the examined socioeconomic factors. Enthusiastic Investors were the only segment whose investment decision was positively affected by all examined economic and social factors, and thus seemed to equally value the economic benefits as well as the social deference associated with investments made by citizens. On the other hand, Indifferent Investors did value neither the economic nor the social factors. Regarding the remaining two clusters, Pro-environmental Investors valued the environmental benefits and the investment conditions, while Social Investors valued the social aspects of the investment. The observed differentiation is a significant contribution of this study because it points at the different motivations underlying citizens' decision to invest in renewable energy.

An implication of the observed heterogeneity is that it points to the possibility that universal policies and market strategies based on "one-size-fits-all" approaches are not successful in attracting citizen investment in renewables. It would be thus highly meaningful to take into account the observed differences in the design of strategies and policies for mobilizing citizen investments. As an example, marketing strategies emphasizing the positive effect of renewable energy investments on the effort to reduce energy production-related greenhouse gas emissions may be successful in attracting investments from citizens identified in the cluster Pro-environmental Investors. As this cluster represents 28.9% in our representative sample, such strategies can be expected to appeal to a substantial part of Greek citizens. Following the same line of thought, it is also necessary to appeal to Social Investors by designing suitable marketing strategies which will feature the ability of RES investments to turn citizens into social advocates of renewable energy in their community and to enhance their social standing as active citizens that proceed with exemplary deeds in favor of the environment. As Enthusiastic Investors valued both economic and social factors, it may not be necessary to design strategies explicitly for this group as strategies targeted towards Pro-environmental and Social Investors will be effective for them. It is also important for policymakers to observe that all clusters exhibited a clear preference for low investment amounts, highlighting the need to establish investment mechanisms that may be more suitable for citizens, but, at the moment, are not diffused in the study area, such as equity co-investments, revenue-sharing dividends, and crowdfunding options.

Table 4. Chi-squared tests results of differences between clusters.

Variable	Scale	CL1 (9.4%)	CL2 (30.5%)	CL3 (28.9%)	CL4 (31%)
Socio-demographic variables					
Occupation	Public employee	17.2%	21.3%	23.8%	15.7%
	Private employee	17.9%	20.5%	23.6%	20.5%
	Freelancer	14.5%	12.4%	9.9%	13%
	Entrepreneur	8.3%	5.5%	2%	4%
	Homemaker	6.2%	5.8%	4.7%	7.3%
	Crop farmer	6.2%	7.5%	3.8%	5.9%
	Livestock farmer	2.1%	2.1%	1.3%	1.9%
	Retired	15.2%	14.7%	18.7%	14.5%
	Unemployed	12.4%	10.2%	12.1%	17.2%
Education level	Primary school	22.1%	15.1%	17.3%	18.9%
	Lower secondary school	6.2%	9.0%	4.9%	8.2%
	Technical school	3.4%	2.3%	1.6%	4.2%
	Vocational training school	4.8%	8.7%	7.2%	6.9%
	Upper secondary school	17.2%	22.0%	16.9%	24.3%
	Vocational education and training (VET)	12.4%	10.0%	10.3%	9.9%
	University	20.7%	21.5%	26.1%	19.9%
	Master's degree	10.3%	10.0%	13.3%	6.9%
	Doctoral degree	2.8%	1.3%	2.5%	0.8%
Family status	Unmarried	29.0%	30.9%	42.5%	40.0%
	Married	57.9%	55.7%	48.3%	46.8%
	Divorced	6.2%	5.8%	2.7%	5.9%
	Widowed	6.9%	7.7%	6.5%	7.3%
Income	Less than EUR 5000	13.8%	9.6%	10.8%	11.7%
	EUR 5001–10,000	19.3%	19.6%	17.5%	23.1%
	EUR 10,001–20,000	24.1%	31.1%	33.9%	22.0%
	EUR 20,001–30,000	4.8%	10.7%	6.7%	6.9%
	More than EUR 30,000	6.2%	3.0%	3.4%	4.4%
Information about RES investments	Not at all—it is the first time I have heard that there is such a possibility	11.7%	3.2%	5.2%	6.9%
	Slightly—I know very few things about RES investments	34.5%	28.1%	32.4%	32.1%
	Moderately—I am familiar with the basic types of RES investments	26.9%	39.9%	46.7%	41.1%
	Much—I have a good knowledge about different investments in RES, risks, and return on investments	10.7%	37.0%	22.5%	29.8%
	Very much—I have a detailed knowledge about RES investments	19.3%	20.7%	13.3%	16.4%
Willingness to invest in RES	Unwilling to invest	37.9%	10.0%	23.8%	25.2%
	Less than EUR 500	16.6%	16.4%	17.5%	12.6%
	EUR 500–1000	5.8%	17.5%	17.8%	20.5%
	EUR 1000–2000	17.9%	15.4%	18.7%	17.4%
	EUR 2000–5000	8.3%	13.0%	9.7%	11.3%
	EUR 5000–10,000	4.1%	12.8%	7.4%	6.1%
	EUR 10,000–20,000	0.0%	7.9%	2.5%	2.7%
	>EUR 20,000	4.1%	7.0%	2.7%	4.2%

Our study also indicates discrepancies among the four clusters with regard to the reported levels of willingness to invest in renewable energy. Specifically, most members of the Enthusiastic Investors cluster expressed pronounced investment willingness, whereas Pro-environmental Investors and Social Investors would either invest very low sums of money or would make no investment at all. In essence, this means that a considerable part of citizens would prefer to invest very low sums of money, confirming previous research showing that citizens who are willing to invest generally prefer to invest low sums of money [14]. Moreover, Indifferent Investors exhibited the lowest level of willingness to invest, which can be associated with their low evaluation of the examined socioeconomic reasons. It therefore seems that the negative evaluation of the socioeconomic RES investment factors is related to low willingness to invest, and, therefore, the understanding of citizens' perceptions to socioeconomic factors is highly meaningful in any effort to understand how to mobilize citizen investment in renewables.

The reported levels of willingness to invest may also be associated with each cluster's reported level of knowledge about RES investments. Enthusiastic Investors, for instance, reported knowing much, whereas Indifferent Investors reported knowing very little about RES investments. In this regard, it is likely that increasing the provision of information about RES investments may be the missing link to turn willingness to invest into actual investment for clusters that reported having moderate knowledge about RES investments [20,24].

5. Conclusions

This study sought to examine, for the first time, whether citizens as potential investors in renewable energy can be classified on the basis of how they evaluate socioeconomic reasons affecting their investment decision. Our analysis has managed to provide a comprehensive socioeconomic factor-based classification of the identified citizen investor segments, named as Indifferent Investors, Enthusiastic Investors, Pro-environmental Investors, and Social Investors (representing 9.4%, 30.5%, 28.9%, and 31% of the sample, respectively). These four identified segments exhibit notable differentiation in terms of their evaluation of socioeconomic reasons related to RES investment, suggesting that there is significant differentiation in the way the examined socioeconomic factors affect citizen investment decision. Therefore, citizens should not be approached as a homogeneous target group by marketing experts and policymakers that seek to mobilize citizen investment in RES. Marketing experts and policymakers should also pay attention to the fact that each cluster has demonstrated a different level of willingness to invest in renewable energy, and has also demonstrated knowledge about renewable energy investments. Specifically, high levels willingness-to-invest were also recorded for Enthusiastic Investors (90%), Pro-environmental Investors (76.3%), and Social Investors (74.8%), whereas only 56.8% of Indifferent Investors would invest in renewables. However, all clusters exhibited a clear preference for small investment sums, bringing forward the need to establish investment mechanisms that are suitable for citizens interested in investing small amounts of money. In terms of their knowledge about RES investments, Indifferent Investors (by 61.4%), Pro-environmental Investors (by 79.1%), and Social Investors (by 73.2%) have a slight or moderate knowledge, whereas Enthusiastic Investors (by 57.7%) reported good levels of knowledge. The evaluation of socioeconomic reasons made by each cluster may enable a high level of precision in the design of different marketing strategies for each cluster. This kind of design can also be expected to be more effective in comparison to the one currently applied, because it will be in line with the expressed preferences of citizens.

Finally, the results reported in this paper should be seen in the light of some limitations which also point to new directions for future research. Most importantly, even though this research used a broad and representative citizen sample, it is limited only to Greece. For this reason, the reported results should be interpreted in view of the energy policy framework and the investment environment in the study area. To achieve a level of EU-wide segmentation, it would be both interesting and meaningful to examine how EU citizens evaluate socioeconomic factors in future research. Another limitation was that this study measured socioeconomic factors among citizens that have not invested, and not actual citizen investors. However, the rationale was that through the right policies and a more careful design of investment schemes, citizens can be induced to invest in renewable energy and, in this way, to facilitate the pursued energy transition. That being said, a future cluster analysis using a sample of actual citizen investors may perhaps help design the marketing strategies and policies with even greater precision. In addition, future research dedicated to RES investments should replicate this socioeconomic factor-based cluster analysis in relation to specific investment schemes, such as the feed-in-tariff and the net-metering options currently available to citizens. Finally, this kind of segmentation analysis should be repeated after some time because it is essential to examine the possibility that citizen investors evolve and the ways in which they evolve. In this way, the design of marketing strategies and policies for citizen investment can be updated according to how citizen preferences and perceptions change.

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References

1. European Council Fit for 55. Available online: https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/ (accessed on 5 May 2024).
2. Chatzizacharia, K.; Benekis, V.; Hatziavramidis, D. A blueprint for an energy policy in Greece with considerations of climate change. *Appl. Energy* **2016**, *162*, 382–389. [CrossRef]
3. Spyridaki, N.-A.; Banaka, S.; Flamos, A. Evaluating public policy instruments in the Greek building sector. *Energy Policy* **2016**, *88*, 528–543. [CrossRef]
4. Ministry of Environment and Energy National Inventory Report of Greece for Greenhouse Gases and other Gases for the Years 1990–2021. Available online: https://ypen.gov.gr/wp-content/uploads/2021/06/2021_NIR_Greece.pdf (accessed on 5 May 2024).
5. Karasmanaki, E. Understanding willingness to pay for renewable energy among citizens of the European Union during the period 2010–20. In *Low Carbon Energy Technologies in Sustainable Energy Systems*; Academic Press: Cambridge, MA, USA, 2021; ISBN 9780128228975.
6. European Commission Climate Change-Driving Forces. Eurostat Statistics Explained. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Climate_change_-_driving_forces (accessed on 9 July 2024).
7. Karamaneas, A.; Koasidis, K.; Frilingou, N.; Xexakis, G.; Nikas, A.; Doukas, H. A stakeholder-informed modelling study of Greece's energy transition amidst an energy crisis: The role of natural gas and climate ambition. *Renew. Sustain. Energy Transit.* **2023**, *3*, 100049. [CrossRef]
8. Hellenic Parliament Law 4936/2022–National Climate Law. Available online: https://www.hellenicparliament.gr/Nomothetiko-Ergo/Anazitisi-Nomothetikou-Ergou?law_id=0b7f36df-2e5b-4d4b-b5f3-ae9900a07542 (accessed on 15 April 2014).
9. Karasmanaki, E.; Galatsidas, S.; Ioannou, K.; Tsantopoulos, G. Investigating Willingness to Invest in Renewable Energy to Achieve Energy Targets and Lower Carbon Emissions. *Atmosphere* **2023**, *14*, 1471. [CrossRef]
10. Zafeiriou, E.; Spinthiropoulos, K.; Tsanaktsidis, C.; Garefalakis, S.; Panitsidis, K.; Garefalakis, A.; Arabatzis, G. Energy and Mineral Resources Exploitation in the Delignitization Era: The Case of Greek Peripheries. *Energies* **2022**, *15*, 4732. [CrossRef]
11. Willis, K.; Scarpa, R.; Gilroy, R.; Hamza, N. Renewable energy adoption in an ageing population: Heterogeneity in preferences for micro-generation technology adoption. *Energy Policy* **2011**, *39*, 6021–6029. [CrossRef]
12. Masini, A.; Menichetti, E. Investment decisions in the renewable energy sector: An analysis of non-financial drivers. *Technol. Forecast. Soc. Change* **2013**, *80*, 510–524. [CrossRef]
13. Collier, S.H.C.; House, J.I.; Connor, P.M.; Harris, R. Distributed local energy: Assessing the determinants of domestic-scale solar photovoltaic uptake at the local level across England and Wales. *Renew. Sustain. Energy Rev.* **2023**, *17*, 113036. [CrossRef]
14. Sirr, G.; Power, B.; Ryan, G.; Eakins, J.; O'Connor, E.; le Maitre, J. An analysis of the factors affecting Irish citizens' willingness to invest in wind energy projects. *Energy Policy* **2023**, *173*, 113364. [CrossRef]
15. Vasseur, V.; Kemp, R. A segmentation analysis: The case of photovoltaic in the Netherlands. *Energy Effic.* **2015**, *8*, 1105–1123. [CrossRef]

16. Salm, S.; Hille, S.L.; Wüstenhagen, R. What are retail investors' risk-return preferences towards renewable energy projects? A choice experiment in Germany. *Energy Policy* **2016**, *97*, 310–320. [CrossRef]
17. le Maitre, J.; Ryan, G.; Power, B.; Sirr, G. Mechanisms to promote household investment in wind energy: A national experimental survey. *Renew. Energy* **2024**, *220*, 119557. [CrossRef]
18. Wilson, C.; Dowlatabadi, H. Models of Decision Making and Residential Energy Use. *Annu. Rev. Environ. Resour.* **2007**, *32*, 169–203. [CrossRef]
19. Shwom, R.; Lorenzen, J.A. Changing household consumption to address climate change: Social scientific insights and challenges. *Wiley Interdiscip. Rev. Clim. Change* **2012**, *3*, 379–395. [CrossRef]
20. Aguilar, F.X.; Cai, Z. Exploratory analysis of prospects for renewable energy private investment in the U.S. *Energy Econ.* **2010**, *32*, 1245–1252. [CrossRef]
21. Curtin, J.; McInerney, C.; Gallachóir, B.Ó.; Salm, S. Energizing local communities—What motivates Irish citizens to invest in distributed renewables? *Energy Res. Soc. Sci.* **2019**, *48*, 177–188. [CrossRef]
22. Guetlein, M.C.; Schleich, J. Understanding citizen investment in renewable energy communities. *Ecol. Econ.* **2023**, *211*, 107895. [CrossRef]
23. Vasseur, V.; Kemp, R. The adoption of PV in the Netherlands: A statistical analysis of adoption factors. *Renew. Sustain. Energy Rev.* **2015**, *41*, 483–494. [CrossRef]
24. Gamel, J.; Menrad, K.; Decker, T. Is it really all about the return on investment? Exploring private wind energy investors' preferences. *Energy Res. Soc. Sci.* **2016**, *14*, 22–32. [CrossRef]
25. Faiers, A.; Neame, C. Consumer attitudes towards domestic solar power systems. *Energy Policy* **2006**, *34*, 1797–1806. [CrossRef]
26. Schelly, C. Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters. *Energy Res. Soc. Sci.* **2014**, *2*, 183–191. [CrossRef]
27. Jager, W. Stimulating the diffusion of photovoltaic systems: A behavioural perspective. *Energy Policy* **2006**, *34*, 1935–1943. [CrossRef]
28. Yee, C.H.; Al-Mulali, U.; Ling, G.M. Intention towards renewable energy investments in Malaysia: Extending theory of planned behaviour. *Environ. Sci. Pollut. Res.* **2022**, *29*, 1021–1036. [CrossRef] [PubMed]
29. Knauf, J.; le Maitre, J. A matter of acceptability? Understanding citizen investment schemes in the context of onshore wind farm development. *Renew. Sustain. Energy Rev.* **2023**, *175*, 113158. [CrossRef]
30. Schiffman, L.G.; Wisenblit, J.; Kumar, S.R. *Consumer Behavior*; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2010.
31. Petrovich, B.; Hille, S.L.; Wüstenhagen, R. Beauty and the budget: A segmentation of residential solar adopters. *Ecol. Econ.* **2019**, *164*, 106353. [CrossRef]
32. Ebers Broughel, A.; Hampl, N. Community financing of renewable energy projects in Austria and Switzerland: Profiles of potential investors. *Energy Policy* **2018**, *123*, 722–736. [CrossRef]
33. Gáspár, S.; Pataki, L.; Barta, Á.; Thalmeiner, G.; Zéman, Z. Consumer Segmentation of Green Financial Products Based on Sociodemographic Characteristics. *J. Risk Financ. Manag.* **2023**, *16*, 98. [CrossRef]
34. Wang, J.; Liu, F.; Li, L.; Zhang, J. More than innovativeness: Comparing residents' motivations for participating renewable energy communities in different innovation segments. *Renew. Energy* **2022**, *197*, 552–563. [CrossRef]
35. Heiskanen, E.; Jalas, M.; Juntunen, J.K.; Nissilä, H. Small streams, diverse sources: Who invests in renewable energy in Finland during the financial downturn? *Energy Policy* **2017**, *106*, 191–200. [CrossRef]
36. Bryman, A. *Social Research Methods—Oxford University Press*; Oxford University Press: Oxford, UK, 2016.
37. Singh, S. *Advanced Sampling Theory With Applications: How Michael "Selected" Amy*; Kluwer Academic Publishers: Alphen aan den Rijn, The Netherlands, 2003.
38. Gupta, S.; Shabbir, J. On improvement in estimating the population mean in simple random sampling. *J. Appl. Stat.* **2008**, *35*, 559–566. [CrossRef]
39. Matis, K. *Forest Sampling*, 2nd ed.; Democritus University of Thrace: Xanthi, Greece, 2001.
40. Pagano, M.; Gauvreau, K.; Mattie, H. *Principles of Biostatistics*; Chapman and Hall/CRC: Boca Raton, FL, USA, 2022; ISBN 9780429340512.
41. Jolliffe, P.M. *Principal Component Analysis*, 2nd ed.; Springer: New York, NY, USA, 2012.
42. Cattell, R.B. *The Scientific Use of Factor Analysis in Behavioral and Life Sciences*; Springer: Boston, MA, USA, 1978; ISBN 978-1-4684-2264-1.
43. Fragos, C.K. *Methodology of Market Research and Data Analysis with the Use of the Statistical Package SPSS for Windows*; Interbooks Publications: Athens, Greece, 2004.
44. Maxwell, A.E.; Harman, H.H. Modern Factor Analysis. *J. R. Stat. Soc. Ser. A* **1968**, *131*, 615. [CrossRef]
45. Ikotun, A.M.; Ezugwu, A.E.; Abualigah, L.; Abuhaija, B.; Heming, J. K-means clustering algorithms: A comprehensive review, variants analysis, and advances in the era of big data. *Inf. Sci.* **2023**, *622*, 178–210. [CrossRef]

46. Dalmaijer, E.S.; Nord, C.L.; Astle, D.E. Statistical power for cluster analysis. *BMC Bioinform.* **2022**, *23*, 205. [CrossRef] [PubMed]
47. Wu, J. Cluster Analysis and K-means Clustering: An Introduction. In *Advances in K-Means Clustering: A Data Mining Thinking*; Springer: Boston, MA, USA, 2012; pp. 1–16.