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Ranking the Barriers to the Energy Upgrading of Buildings Using the Best-Worst Method

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Abstract: The global need to reduce energy demand has led European governments to accelerate their endeavors to achieve their targets regarding nearly zero-energy buildings. Despite the implementation of funding initiatives for the energy upgrading of buildings in EU member states and other European countries, research has shown that the absorption rates of the offered funds remain low. This research aims to assess the significance of the barriers to improving the energy efficiency of Greece's building stock. This is achieved by ranking the identified barriers using the best-worst method (BWM). The innovation provided by this study is that the data obtained are based on the experience of three categories of stakeholders, including professionals in the field, i.e., engineers and skilled workers, and homeowners. The results show that all three groups are discouraged from performing the energy upgrading of buildings due to economic barriers but also technological barriers related to a lack of training in the use of and slow development of related new technologies.

Keywords: energy efficiency; BWM; ranking of barriers; nearly zero-energy buildings (nZEB); green buildings; eco-materials; residential homes

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1. Introduction

Recent research on global energy consumption has identified that the industrial, transport, and building sectors consume the most energy [1]. More specifically, the building sector in the European Union (EU) is responsible for 40% of the EU's total energy consumption and 10% of its total CO_2 emissions [2]. The high energy consumption and increased levels of greenhouse gases produced by this sector come primarily from the increased needs of buildings for heating, cooling, lighting, and using electrical appliances. Hence, the energy upgrading of buildings (EUoB) is one of the most critical areas that needs to be focused on to achieve the EU's sustainability targets regarding the reduction in energy consumption.

In order to align its policies with the EU directives, Greece first made it mandatory to obtain an energy performance certificate based on the methodology defined in the Greek Regulation for the Energy Efficiency of Buildings [3] for new buildings and the sale or renting of existing buildings, and then proceeded to develop the National Energy and Climate Plan (NECP) for 2030 [4] and the Long-Term Strategy (LTS) for 2050 [5]. The LTS is a guide for the transition to a climate-neutral economy by 2050 based on the EU's targets. Its main priorities are to improve energy efficiency, develop renewable energy sources, promote the electrification of transport and heating, and develop alternative domestic fuels, including biomass gas.

To promote these policies for the EUoB, the Greek government has launched a series of energy-saving programs, some of which are co-financed by EU funds. The main objective of these programs is to provide financial assistance to encourage people to invest in the improvement of the energy efficiency of their property. The first program for the energy upgrading of residential homes in Greece was implemented in 2012. A total of seven programs have been implemented so far for the EUoB. These programs differed in terms of the grant or loan amounts, as well as in terms of the income categories of the beneficiaries. A common factor was the eligible expenditure (e.g., the replacement of door and window frames, external insulation, heating system improvements) for the purpose of upgrading the energy performance of buildings. It should also be noted that one of the programs targeted young people with a larger grant (Exoikonomo-Renovate for the young). In addition to the above, a program for public buildings has recently been initiated (Electra, 2022, budget: EUR 640 million), and a program for the energy upgrading of businesses is planned (budget: EUR 200 million).

However, research has shown that the absorption rates of the offered funds remain low [6,7]. Indicative barriers to the EUoB in Greece are the lack of efficient program publicity, the lack of incentives, and the bureaucratic process to be subsidized [6]. In addition, Antoniou et al. [6] found that the reluctance of owners to proceed to the EUoB is also due to their distrust in the capability of workers in using modern eco-materials. These observations are similar to those made by Mulligan et al. [8] regarding barriers to green building policies in the US and particularly the state of Michigan.

This research aims to identify and assess the significance of the barriers that appear in the effort to improve the energy efficiency of Greece's building stock. This is achieved by ranking the barriers identified in the literature and rated by survey participants by using the best-worst method (BWM), a multi-criteria decision-making (MCDM) method. The innovation provided by this study is that the data obtained are based on the experience of three categories of stakeholders through questionnaires, including professionals in the field, i.e., engineers and skilled workers, and homeowners. It was considered particularly important to record the owners' opinions, as they have a significant role in the dissemination of the need for and the implementation of the EUoB, and it was found that only 5 out of the 50 articles reviewed considered their opinions on the challenges involved.

Therefore, the research questions that were formulated are as follows:

1. What are the most significant barriers to the EuoB, according to professional engineers?
2. What are the most significant barriers to the EuoB according to skilled workers?
3. What are the most significant barriers to the EuoB according to homeowners?
4. How do the results compare to international research?

The following section includes a description of the literature review that determined the gap in this literature and provided a comprehensive list of potential barriers to be rated by the survey participants, as elaborated in Section 3. Section 4 describes the BWM and how it was applied to the research problem, including data collection, analysis, and results. Section 5 discusses the results, while the final section includes the conclusions, proposals, limitations, and ideas for further research.

2. Literature Review

Initially, a review and content analysis of the existing literature was carried out to identify the most frequently documented barriers to the EUoB. The literature review was conducted by searching through the scientific research databases Scopus, Science Direct, and Google Scholar. Three searches using the following phrases as keywords were conducted: "Green buildings barriers", "energy efficiency buildings barriers", and "energy-efficient buildings barriers". The first returned 890, the second returned 1068, and the third returned 697 documents, thus verifying the observations of Cristino et al. [9], who found that research in the field of energy efficiency in the construction industry has been particularly prolific in the last decade showing an increasing trend over the last twenty years (Figure 1).

Initial observations included the fact that, in the last two decades, there has been a large amount of research in the field of sustainable development and the EUoB. In addition, terms such as "green buildings", "near-zero net carbon buildings (nZCB)", and "near-zero energy buildings (nZEB)" have appeared. Researchers such as Wilson and Tagaza [10], Richardson and Lynes [11], Mokhtar Azizi et al. [12], and Zhang et al. [13] investigated these issues, while others dealt with the energy efficiency rating systems [14,15].

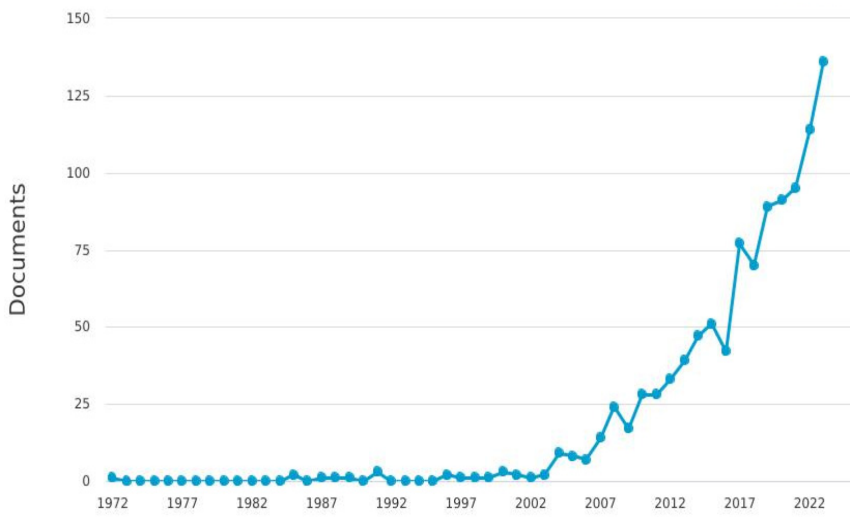

Figure 1. Number of documents published per year in Scopus-indexed journals returned following the keyword search "Green buildings barriers".

A total of 50 publications, which included references to barriers encountered in the effort to upgrade the energy performance of buildings, were selected and underwent a detailed content analysis. The inclusion criteria for the selection of the 50 publications were articles that were published in journals and that examined barriers encountered in the EUoB, excluding industrial buildings. The chronological distribution of publications studied in this research is shown in Figure 2.

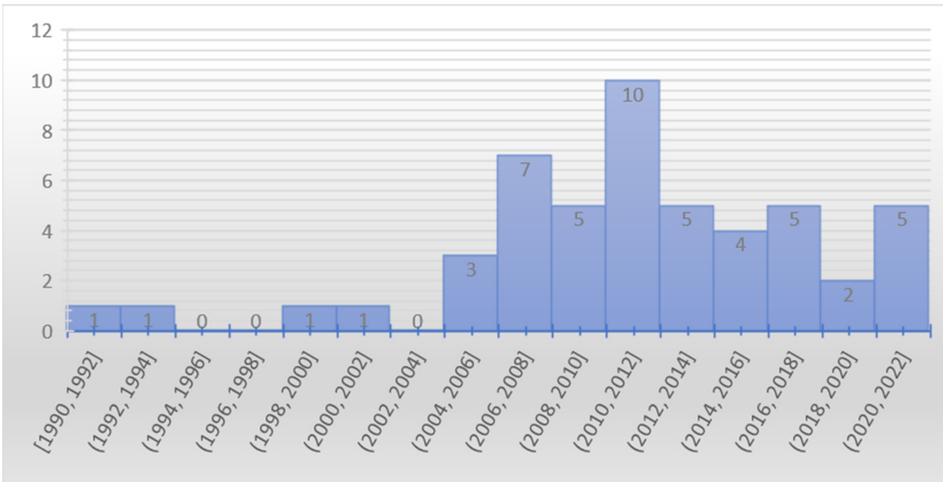

Figure 2. Chronological distribution of publications studied in this research.

Five of the fifty papers studied that were published from 2014 onwards attempted to rank barriers. Each study grouped the barriers differently into three to six categories. After categorization, the barriers are ranked according to their significance but with a different methodology in each study [9,16–19]. As far as the evaluation and rating of the significance of the barriers are concerned, these studies used different methods to derive their conclusions. In most studies, the opinion of experts in the building construction sector, whether they were engineers, contractors, or researchers in the field of energy efficiency, was requested to verify the existence of the observed barriers. In addition, publications were found that focused on a specific category of barriers, such as institutional barriers [20] and market barriers [21]. Other publications investigated those factors that prevent the EUoB in a specific region, such as China [22,23], the UK [24], and Ghana [17]. The gap found in these studies is that the opinion on the significance of the barriers was rarely sought from building owners who might be interested in upgrading the energy performance of their properties. Of the papers studied, only five [6,25–28] referred to owners.

As Greece has a 73.3% owner-occupancy rate, which is above the European Union average of 69.9% [29], the opinion of homeowners should be acknowledged. Also important is the opinion of the skilled workers, as they will be entrusted with the implementation of new methods for the EUoB, and according to the literature, skilled workers are considered one of the barriers to energy upgrading, as they are not considered adequately qualified in the use of green technologies [6].

These gaps were addressed in this paper by first collecting and categorizing the barriers that appear in the literature and then analyzing the data from the questionnaire survey by using the best-worst MCDM method. The questionnaires were distributed to engineers with experience in energy retrofitting (architects, civil engineers, energy inspectors), to skilled workers with experience in specific upgrading jobs (insulation, heating-plumbing installations, window frames, shading systems), and to homeowners.

3. Barriers to the EUoB

From the content analysis of the 50 selected articles, 289 barriers were recorded. After removing duplicates and performing an in-depth investigation of the remaining barriers to combine similar ones, 19 barriers emerged. Then, the barriers were divided into five categories, namely economic, institutional, professional and social, market, and technological barriers, in accordance with those used by Cristino et al., Djokoto et al., and Gupta et al. [9,17,18]. Table 1 shows all the papers and the barriers that each one referred to, while Table 2 presents their final categorization.

Table 1. Table of barriers per paper.

Reference		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19
Antoniou et al. [6]	2022												✓				✓	✓		
Austin [30]	2012		✓									✓						✓		
Moktar Azizi et al. [12]	2010	✓			✓	✓		✓		✓	✓	✓					✓			
Bagaini et al. [19]	2020		✓	✓			✓		✓	✓	✓	✓	✓					✓		
Berardi [31]	2011							✓				✓			✓					
Blomqvist et al. [26]	2022							✓		✓							✓			
Bloom et al. [15]	2011	✓	✓		✓	✓					✓	✓								
Bruce et al. [32]	2014	✓	✓			✓	✓						✓	✓						
Bui et al. [33]	2022	✓	✓			✓	✓			✓			✓		✓			✓		
Chegut et al. [16]	2013		✓		✓							✓				✓				
Chan et al. [34]	2018	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓		✓	✓
Cristino et al. [9]	2021	✓	✓	✓		✓	✓	✓		✓	✓		✓			✓		✓	✓	✓
Dadzie et al. [35]	2018	✓			✓		✓				✓	✓	✓				✓	✓		
Darko et al. [36]	2018					✓	✓	✓		✓								✓	✓	
Djokoto et al. [17]	2014	✓			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓	
Ebekozien et al. [37]	2021	✓				✓	✓	✓		✓	✓						✓	✓		
Gliedt and Hoicka [25]	2015	✓	✓	✓														✓		
Griffin et al. [14]	2010				✓		✓					✓		✓	✓	✓	✓		✓	
Gupta et al. [18]	2017		✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	
Häkkinen et al. [38]	2011				✓		✓		✓		✓					✓		✓		✓
Harmelink et al. [39]	2008						✓	✓	✓					✓						
Hirst and Brown [40]	1990			✓		✓	✓	✓				✓						✓		
Jakob [28]	2007	✓	✓		✓	✓	✓			✓										
Jones [41]	2015			✓				✓		✓		✓								
Karkanias et al. [42]	2010				✓	✓	✓		✓		✓		✓		✓					
Landman [43]	1999	✓			✓					✓						✓				
Langlois-Bertrand [44]	2015							✓												
Leung et al. [45]	2013			✓		✓	✓				✓									
Martin and Gossett [46]	2012		✓	✓																
IEA [21]	2007		✓	✓				✓			✓									
Moore [47]	1994		✓	✓		✓		✓			✓		✓					✓		

Table 1. *Cont.*

Reference		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19
Peterman et al. [48]	2012		✓				✓				✓								✓	
Du et al. [22]	2014	✓	✓	✓			✓			✓	✓					✓			✓	
Pitt et al. [49]	2009						✓	✓			✓					✓	✓		✓	
Power [50]	2008					✓	✓	✓												
Li et al. [51]	2020					✓	✓			✓								✓	✓	
Richardson and Lynes [11]	2007	✓				✓		✓		✓	✓				✓				✓	
Samari et al. [52]	2013	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	
Shen et al. [53]	2017	✓				✓	✓	✓		✓	✓		✓				✓			
Theodoridou et al. [54]	2011	✓							✓						✓		✓			
van Bueren et al. [20]	2002														✓		✓			
Williams and Dair [24]	2006	✓			✓						✓		✓				✓			
Wilson and Tagaza [10]	2006																✓	✓	✓	
Richardson and Lynes [11]	2016		✓			✓	✓	✓	✓	✓	✓		✓				✓			
Winston [55]	2010			✓		✓	✓	✓							✓		✓			
Wood [56]	2007				✓	✓	✓			✓			✓					✓		
WBC [57]	2007				✓			✓		✓	✓						✓	✓		
Yao and Li [23]	2005				✓		✓	✓												
Zhang et al. [13]	2011				✓	✓		✓			✓									
Zhang et al. [58]	2012							✓			✓			✓			✓			
Frequency of occurrence		18	17	14	18	23	28	26	8	21	25	13	14	6	10	10	18	17	13	3

Table 2. Barriers to the EUoB in Greece.

Category	Code	Barriers
Economic Barriers (K1)	E1	High initial cost
	E2	Low rate of return on investment, low profitability
	E3	Lack of funds and difficulty in securing loans
	E4	High final and maintenance costs
Institutional Barriers (K2)	E5	Insufficient incentives
	E6	Lack of guidelines, instructions and evaluation standards
	E7	Weak political will. Different priorities
	E8	Absence of a proper building database
Professional and Social Barriers (K3)	E9	Inexperienced and unskilled professionals
	E10	Low awareness and lack of information
	E11	Fear of failure. Doubt about achieving desired goals
	E12	Prejudice against practices
	E13	Delays in work schedule
	E14	Cooperation between different groups of employees
Market Barriers (K4)	E15	Doubt from the markets about the demand for the products
	E16	Building materials (availability, cost, durability, reliability)
	E17	Insufficient public information and promotion of materials
Technological Barriers (K5)	E18	Incompatible technology. Slow development
	E19	Absence of exhibitions promoting new technologies

3.1. Economic Barriers

Economic barriers are one of the most critical categories, especially in Greece, as the country is struggling to return to growth after more than a decade of economic crisis. More specifically, high initial costs (E1) are defined as the funds required to start the works and purchase the materials for the EUoB. Indeed, these costs may be high as the replacement of heating units, for example, may require a complete replacement rather than a simple retrofit. In addition, the installation of solar water heaters and insulation and other works are also considered expensive.

Nevertheless, another economic barrier is the low return on investment (E2). This is because retrofits are costly, resulting in the properties needing more time to recoup these high costs. In addition, the homeowners may not live in the energy-upgraded property, so they may not benefit directly. For example, even if they increase the rental price, it still is not guaranteed that there will be a profit from this action. Instead, the tenant will feel immediate benefits with lower heating costs for example. Considering the above, it can be observed that landlords remain reluctant to upgrade the energy efficiency of their property investments. This problem (split incentives) is much more common in other EU countries, especially in larger cities, as there are lower rates of owner-occupation in these countries compared to Greece.

Greece's socio-economic situation is at a different level than before the economic crisis. As a result, incomes have fallen significantly, and the funds available to citizens for investments such as in the EUoB are limited (E3). In addition, the financial crisis has also limited the frequency of bank loans. The last economic barrier is the final cost for the EUoB (E4). Upgrading older buildings carries the risk of additional work that may have yet to be foreseen. Also, secondary costs such as design fees and energy performance certificate costs have nothing to do with the required work but increase the final cost. It is also necessary to calculate the maintenance costs of the new improvements so that the rate of depreciation of the initial investment is minimized over the years.

3.2. Institutional Barriers

In addition to economic barriers, institutional barriers are also significant as they refer to the institutions, rules, and policies that can hinder investment. The political instability of previous years has resulted in governments not having the capacity to eliminate institutional barriers. Such barriers include insufficient incentives, a lack of guidelines, instructions, and evaluation standards, weak political will, different priorities, and the absence of a suitable building database.

Sometimes governments need to be able to provide the necessary incentives, either in the form of subsidies or tax exemptions, to make it easier for those concerned (E5). In other cases, the incentives provided have strict inclusion criteria with limited beneficiaries The European Union also assists by providing various funding programs, although the demand still needs to be met.

Varying governmental priorities may have led to the most prevalent barrier in the literature, which is the need for more guidelines and instructions (E6). This barrier, investigated in 28 out of the 50 studies, may discourage someone who expresses interest in energy upgrading but needs help in understanding the actions required. The absence of strict regulations when constructing or renovating buildings allows buildings to be built without the necessity of making them energy efficient. The primary objective in such cases is obtaining low construction or renovation costs rather than energy upgrading. According to the literature, in many parts of the world, there is no system for classifying buildings according to their energy performance, nor are there the necessary tools for their evaluation. Indeed, this is the case in less developed countries such as Ghana and Nigeria [17,34,36,37] or in countries with different priorities, such as China [52]. In the EU, stringent regulations and standards have now been set for both new buildings and the upgrading requirements for old buildings put to new uses.

Weak political will and different priorities (E7) are barriers to the EUoB in Greece because of the economic crisis and the COVID-19 pandemic, in accordance with the second most frequent barrier found in the literature. Different priorities that existed, such as reductions in labor costs and tax increases on materials and services, significantly reduced the construction of new buildings. However, the subsequent increase in energy prices because of the war between Ukraine and Russia brought to the forefront the need to limit energy consumption globally. Consequently, the climate regarding this barrier is beginning to reverse.

The last of the institutional barriers is the absence of building databases (E8). This is considered particularly critical as their use would enable more targeted upgrades. However, the absence of a database with the characteristics and requirements of each region, which are different (mountainous, island regions), and of a database with the architectural, structural, and construction characteristics of buildings in Greece makes it difficult to upgrade them more efficiently in terms of energy consumption.

3.3. Professional and Social Barriers

This category includes all those barriers that are related to people directly involved in the EUoB. They refer to difficulties that arise for professionals and homeowners. They are related to the inexperience of professionals in the application of new methods, new techniques, and the choice of materials necessary for the upgrading of buildings (E9). Regarding owners, there are problems of low awareness and information (E10), fear of failure and doubt about achieving the efficient EUoB (E11), and prejudice against new practices (E12). In addition, both professionals and owners may be discouraged by the increased time required (E13) and by the need for cooperation between multiple worker groups (E14).

The increasing demand for new types of energy-efficient materials, which require the necessary expertise to be applied and installed, has raised the problem of training professionals (E9). Both skilled workers and engineers need to be informed and trained in new techniques so that neither they nor the building owners who employ them feel insecure.

Lack of public awareness (E10) about energy efficiency of buildings, green buildings and all these new terms is the third most frequent barrier found in the literature. Efforts have recently been made to overcome this barrier prompted by the rise in energy prices, which has encouraged people to seek more environmentally friendly forms of energy for their economic benefit.

The fear of failure and doubt about achieving the desired energy efficiency goals of an energy upgrade plan is an emotional problem (E11), which can have a significant influence on the decision to proceed with energy upgrading because it causes anxiety and inhibitions. Furthermore, many owners, considering the size of the investment they will have to make to perform energy upgrading and needing to know the benefits, find it difficult to decide to upgrade their home.

A further cultural and social factor that has been recorded as having an impact on energy upgrading is the perceptions and attitudes of a community (E12). For example, some communities may need help adopting new technologies or techniques as they are used to and trust their traditional practices.

Delays in the work schedule are a problem frequently observed in all construction projects (E13). This is due to the number of complex activities involved. It is also considered a deterrent for cases where energy upgrading activities need to be executed in occupied buildings, which require additional coordination and communication skills.

Finally, a perceived professional barrier is the need for successful cooperation between different groups of workers (E14). For example, if there is no interaction between the external insulation contractor and the contractor who is to replace the door and window frames, they may not be installed correctly. This has the consequence of creating confusion, resulting in delays and poor quality.

3.4. Market Barriers

The category of barriers arising from the difficulties encountered in the market sector also makes an essential contribution to the obstructions to the EUoB. Companies are reluctant to invest in new products since consumer interest is low (E15). Customers are not interested in using new materials and techniques such as smart windows, vacuum insulating panels, or green roofs [6] to reduce the energy consumption of their homes or believe that they do not need them. The availability, cost, durability, and reliability of materials (E16) are also mentioned in the literature as a barrier. The availability of materials in local markets can be a significant risk during the construction stage. A lack of domestic suppliers may further complicate things, since it raises the cost of already more expensive environmentally friendly materials when they need to be imported. In addition, there is doubt about their reliability and durability over time as compared to the standard materials. The last market barrier concerns the lack of product promotion by companies to consumers (E17). Consumers are defined as the engineers and skilled workers who will use the materials and recommend them to the owners. Their lack of information means that they do not choose and do not trust newer products and tools [6].

3.5. Technological Barriers

Technological barriers include the incompatibility of systems (E18), which refers to the case where the required new technologies are not compatible with the existing infrastructure. Older buildings and infrastructure may need additional design and planning to support green technologies. Finally, the absence of exhibitions promoting green technologies (E19) can lead to insufficient knowledge and information about green technologies and their potential. Therefore, the lack of exhibitions could make it more difficult for the public and professionals to accept and adopt green technologies. Also, the absence of exhibitions may limit the development and improvement of green technologies.

4. Methodology

4.1. Best-Worst Method

MCDM methods are an essential part of the science of decision-making. Their purpose is to develop techniques and models for analyzing and solving problems in which decisions must be made based on multiple criteria. Through these methods, the comparison of options based on multiple criteria is achieved, allowing analysts and decision-makers to make more focused choices [59]. MCDM methods involve a process of gathering, evaluating, and comparing criteria to reach the final decision. Expert experience, judgment and input are used to evaluate each alternative against each criterion. By using these methods, it is possible to achieve a balanced and informed decision that considers the various aspects and priorities involved in the problem. Furthermore, MCDM methods have contributed significantly to the development of risk assessment methods by allowing the ranking of a list of occupational safety risks [60], delay factors [61] or environmental impacts [62]. By using MCDM methods, the decision-maker can evaluate the different options (in this case, barriers) to achieve a ranking in terms of their significance.

The BWM is one such method, introduced by Rezaei [63] to address some issues presented by the analytical hierarchy process (AHP), which until then was the most widely used method [64]. As Malek and Desai [65] noted, AHP leads to consistent and reliable results when there are many options to consider, and consequently, many comparisons are required. In contrast, in the BWM, fewer comparisons are made. The decision-maker first selects the best and worst criteria (barriers) and conducts pairwise comparisons between them and the other criteria. By solving this problem, the weights of the criteria are found. By using the same procedure, when comparing alternatives against each criterion, partial scores of the alternatives are calculated. The final scores of the alternatives are derived from the overall evaluation of the criteria weights and the alternative partial scores per criterion. A consistency check of the evaluations is also performed to ensure the reliability of the comparisons.

Compared to other MCDM methods, the BWM has certain features that set it apart and make it very popular among researchers [66]. First, it requires a smaller number of comparisons as the decision-maker compares and evaluates only the best and worst criteria relative to each other. Moreover, continuous comparisons are made with more reliable results. Based on statistical analyses, the BWM has a significantly better performance compared to the AHP [67].

The process begins with the identification of the criteria ($c_1, c_2, \ldots, c_n$) against which alternative options will be compared to arrive at a decision. In this study, the five barrier categories served as these criteria. Secondly, the decision-maker chooses which of the criteria is the best/most significant and which is the worst/least significant. In this step, no comparison is made using a numerical scale; only the selection of these two criteria is made. Essentially, this process can also be considered a comparison, since to select the best and the worst criteria, the options must be compared intuitively. In this study, the "best" category was the category that posed the most significant barriers to the EUoB, while the "worst" included the least significant barriers. Next, every other criterion (category) was compared against the best and worst ones using the numerical scale as defined in Table 3, adapted for this research.

Table 3. Best-worst method criteria scale adapted for this study.

Numerical Scale	Meaning
1	Equal significance
2	Somewhere between equal significance and moderately more significant
3	Moderately more significant
4	Somewhere between moderately and strongly more significant
5	Strongly more significant
6	Somewhere between strongly and very strongly more significant
7	Very strongly more significant
8	Somewhere between very strongly and extremely more significant
9	Extremely more significant

It is noteworthy that the scale used in the BWM is the same as the scale used in the AHP. The evaluation of the best criterion against all other criteria is carried out using this scale. As a result, the best-to-others vector, $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$, is produced, where a_{Bj} indicates the preference of the best criterion (B) over the j criterion. Similarly, the evaluation of the other criteria (j) against the worst criterion (W) is again achieved using the numerical scale of 1 to 9, resulting in the others to worst vector, $A_w = (a_{1W}, a_{2W}, \ldots, a_{nW})$ where a_{jW} indicates the preference of the j criteria over the worst W.

Finally, the optimal weights for each criterion are those where for each pair w_B/w_j and w_j/w_w, we have $w_B/w_j = a_{Bj}$ and $w_j/w_w = a_{jW}$. To determine the weights, the following equation must be solved:

$$\text{Min Max j} \left\{ \left| \frac{w_B}{w_j} - a_{BJ} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\} \tag{1}$$

subject to

$$\sum_{j=1}^{n} w_j = 1, w_j \geq 0, \text{for every j}$$

The above Equation (1) can be transformed into the following equation:

$$\min \xi \tag{2}$$

subject to

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi, \text{for every j}$$

$$\left| \frac{w_j}{w_w} - a_{jW} \right| \leq \xi, \text{for every j}$$

$$\sum_{j=1}^{n} w_j = 1, w_j \geq 0, \text{for every j}$$

A pairwise comparison model is considered consistent

$$\text{if } a_{Bj} \times a_{jW} = a_{BW}, \text{for every j} \tag{3}$$

where a_{BW} is the preference for the best against the worst criterion.

However, it is expected to allow a pairwise comparison system to deviate to some extent from the absolute consistency of the above relationship. For this reason, it is necessary to have a ratio that indicates the degree of coherence or consistency ratio in the decision-maker's responses. The degree of consistency in the original BWM is measured by determining ξ^*, which is the optimal value (the output) of the optimization model. Hence, it was named by Rezaei [63] output-based consistency measurement. The output-based consistency ratio (CR^O) is given as follows:

$$CR^O = \frac{\xi^*}{\xi max} \quad (4)$$

where ξ^* is the optimal value of Equation (2) and ξmax is the maximum ξ from the solutions to Equation (5)

$$\xi^2 - (1 + 2a_{BW})\xi + \left(a_{BW}^2 - a_{BW}\right) = 0 \quad (5)$$

The range of CR^O is [0.1]. The closer the CR^O value is to 0, the more consistent the answers are. More specifically, if CR^O = 0, then the responses are perfectly consistent.

The consistency ratio of the responses calculated in the initial BWM could only be obtained after the process was completed, which did not give the decision-maker an immediate insight into the consistency of their responses. To overcome this problem and to provide an immediate insight into the level of consistency of responses to the decision-maker, Liang et al. [68] proposed the measurement of consistency based on input. This is achieved using the input provided (i.e., their preferences) without the need to complete the consistency check process. Hence, it was called the input-based consistency ratio (CR^I).

The consistency ratio based on the CR^I is expressed as follows:

$$CR^I = \binom{max}{j} CR_j^I \quad (6)$$

where

$$CR_j^I = \begin{cases} \dfrac{\left|a_{Bj} \times a_{jW} - a_{BW}\right|}{a_{BW} \times \binom{a_{BW}}{0} - a_{BW}} & a_{BW} > 1 \\ & a_{BW} = 1 \end{cases}$$

CR^I is the overall degree of consistency based on the inputs for all criteria.

CR_J^I represents the level of consistency associated with criteria j.

4.2. Data Collection

Data were collected using questionnaires to allow the researchers to capture the views of people who are not particularly familiar with the use of computers (for example, homeowners). Google Forms was used as a freely accessible application to convert the BWM-solving tool into a questionnaire.

Using the BWM solving tool, it was possible to verify the consistency of the responses directly. However, since responses were obtained through a questionnaire and were not provided by the respondent using the BWM solver tool directly, as most were not familiar with the use of MCDM methods, it was preferred that the questionnaire be completed in the presence of the researcher to check the consistency of the responses and point out any possible mistakes. The questionnaire was distributed to engineers and skilled workers who are professionally involved in EUoB and to homeowners as investors and beneficiaries of funding programs. All skilled workers and most homeowners provided responses in the presence of the researcher to provide immediate explanations at any point in the process where clarification was required. In contrast, the group of engineers answered the questionnaire without the presence of the researcher.

It should be noted that there are advantages and disadvantages to questionnaire-based surveys, where responses are given in the presence of the researcher. The main advantages are the ability of the researcher to clarify the questions and verify how seriously the research was taken by the respondent/interviewee. On the other hand, the disadvantage of this practice is that responses may be inadvertently and unconsciously influenced by the researcher [69]. In the initial stage of the questionnaire design, attention was given to the composition of the questions so that the process of pairwise comparisons would be easy to understand even when the researcher was not present.

A draft was given to two colleagues (1. Surveyor Engineer, MSc; 2. Civil Engineer, MSc) to record any omissions in the structure of the questionnaire and comprehension difficulties. After assessing their feedback, the questionnaire was finalized. It was considered that it would be easier for respondents to make comparisons using a smaller rating scale than the one used in the BWM. The rating scale selected was a 1 to 5 rating scale instead of the 1 to 9 numerical scale used by the BWM. The correlation was as follows:

- 1 = 1 (Equal significance)
- 3 = 2 (Moderately more significant)
- 5 = 3 (Strongly more significant)
- 7 = 4 (Very strongly more significant)
- 9 = 5 (Extremely more significant)

Eliminating the intermediate values (2, 4, 6, 8) simplified the process considerably. Of course, it created more challenges in the final processing of the answers, which had to be converted back to the 1 to 9 scale so that the BWM solver could be used.

The questionnaire was distributed to three groups: engineers, skilled workers, and homeowners. In the first group, ten engineers were selected who have experience in the EUoB at various stages of the process, i.e., one architectural engineer with experience in energy design and bioclimatic architecture, seven civil engineers with experience in construction, renovation, and the EUoB, and two mechanical engineers who work as energy inspectors. The group of engineers were given clear instructions on the process of rating and comparing options according to the BWM and were informed about the purpose of the work.

The second group, the skilled workers, consisted of ten (10) people who have various specialties and have been actively involved for several years in various fields. More specifically, the questionnaire responses were provided by four skilled workers involved in residential insulation, three skilled workers involved in energy-efficient window frames, two skilled workers involved in solar water heater and gas installation, and one skilled worker involved in shading systems.

The owners were of all age levels and from different regions. People from urban centers, the countryside, and the Greek islands took part in the survey. In total, 53 responses were obtained from owners who had made energy upgrades to their homes.

Initially, it was considered appropriate to create two questionnaire forms, one for the engineers and skilled workers and another for the owners. This was achieved to make it easier to process the responses later and to clearly separate the responses of the professionals from the owners' responses. The only difference between the two forms was that the first question asked the professionals (engineers and skilled workers) about their years of experience in the EUoB. In contrast, the homeowners were asked if they had made energy upgrades to their property. Afterwards, the respondent's email address was optionally asked for in both forms, and before the BWM comparisons began, there was a short informative text about the process explaining the scale on which the pairwise comparisons would be made.

The BWM begins with selecting the best (most significant) alternative. In the case of the present research, which aimed to rank the barriers to the EUoB, the best option was the one that discourages people from undertaking the process of energy upgrading and is considered the most significant obstacle to the EUoB. The first question was "Select which category of barriers to energy upgrading you consider to be the most significant", with the following options:

- Economic barriers (Cost, revenue, financing)
- Institutional barriers (Guidelines-Laws, political determination, databases)
- Professional and social barriers (knowledge, experience, awareness, doubts about the new)
- Market barriers (Building materials: availability, cost, durability, reliability)
- Technological barriers (Slow development and promotion of new technologies)

Next, the method compared the best (most significant) category chosen by the decision-maker with the other alternatives. For the convenience of the respondents, a Google Forms option was used whereby selecting an answer from the previous question, for example, "institutional barriers", forwarded the respondent to the next question in which the option "institutional barriers" had been eliminated from the answers, i.e., "How much more significant do you consider the Institutional Barriers category compared to the other categories?", having option to rate and compare the institutional barriers category against the others using a scale of 1–5.

Then, the worst (least significant) category was selected from the rest of the option by responding to the question "Select which category you consider as the least significant category of barriers to energy upgrading", with the following options to respond:

- Economic barriers (Cost, revenue, financing)
- Professional and social barriers (knowledge, experience, awareness, doubts about the new)
- Market barriers (Building materials: availability, cost, durability, reliability)
- Technological barriers (Slow development and promotion of new technologies)

As shown above, to avoid confusion, the "Institutional Barriers" option was excluded. The remaining barriers were then compared against the worst (least significant) alternative. For example, if "Market Barriers" was selected as the least significant category in the previous question, the following question was "How much more significant do you consider other categories to be than the Market Barriers category?", having option to compare the market barriers category against the others using a scale of 1–5.

This procedure was carried out six times in total: one time for ranking the categories (economic barriers, institutional barriers, professional and social barriers, market barriers, technological barriers) and once for ranking the barriers in each of the five categories separately.

To sum up, the data collection stage consisted of the following steps:

1. Identification and categorization of barriers.
2. Converting the BWM solver into a questionnaire.
3. Use of feedback from two engineers to optimize the questionnaire.
4. Finalization of the questionnaire.
5. Questionnaire distribution to 10 engineers, 10 skilled workers, and 53 owners.
6. Conversion of data from a scale of 1–5 to a scale of 1–9 for application of the BWM solver.

4.3. Data Analysis

Tables 4–8 below show the responses given by each engineer, after conversion to a scale of 1–9. For each group of responses, we used the BWM solver, except for the technological barriers group, since it included only two barriers for comparison. The BWM solver calculates the weights for each barrier category and the partial scores for each barrier in each category. Also, the BWM solver gives us the input-based consistency ratio (CR^I) for each response, as shown in Tables 4–8. The results consistently provided a low CR^I, close to 0, indicating consistent responses throughout.

Table 4. Pairwise comparison ratings of barrier categories by the engineers.

	Specialty	Experience	Barrier Categories												
			BEST	K1	K2	K3	K4	K5	WORST	K1	K2	K3	K4	K5	CR^I
1	Architect	10+	K1	1	7	5	5	9	K5	9	3	5	5	1	0.22
2	Civil Eng.	5–10	K2	1	1	3	5	3	K4	5	5	3	1	3	0.2
3	Civil Eng.	5–10	K2	3	1	5	3	3	K3	3	3	1	3	3	0.2
4	Civil Eng.	10+	K1	1	3	1	5	1	K4	3	3	3	1	1	0.2
5	Civil Eng.	10+	K1	1	7	3	9	7	K4	9	3	7	1	1	0.17
6	Civil Eng.	5–10	K1	1	9	7	9	9	K2	9	1	3	3	3	0.25
7	Civil Eng.	5–10	K2	9	1	5	5	5	K1	1	9	5	5	5	0.22
8	Civil Eng.	10+	K1	1	3	7	9	7	K4	9	7	3	1	3	0.17

Table 4. *Cont.*

	Specialty	Experience	Barrier Categories											
			BEST	K1	K2	K3	K4	K5	WORST	K1	K2	K3	K4	K5	CR^I
9	Mech. Eng.	10+	K1	1	7	7	9	7	K4	5	3	3	1	3	0.17
10	Mech. Eng.	10+	K1	1	7	5	3	9	K5	9	3	3	7	1	0.17

Table 5. Pairwise comparison ratings of economic barriers provided by the engineers.

	Specialty	Experience	Economic Barriers										
			BEST	E1	E2	E3	E4	WORST	E1	E2	E3	E4	CR^I
1	Architect	10+	E4	5	7	5	1	E2	3	1	3	7	0.19
2	Civil Eng.	5–10	E3	1	3	1	3	E2	3	1	3	1	0
3	Civil Eng.	5–10	E3	1	5	1	3	E2	3	1	3	1	0.1
4	Civil Eng.	10+	E3	1	7	1	3	E2	1	1	3	3	0.14
5	Civil Eng.	10+	E2	1	1	5	9	E4	7	9	3	1	0.08
6	Civil Eng.	5–10	E3	9	7	1	5	E1	1	3	9	3	0.17
7	Civil Eng.	5–10	E1	1	9	5	5	E2	9	1	5	5	0.22
8	Civil Eng.	10+	E3	5	9	1	9	E2	3	1	9	3	0.25
9	Mech. Eng.	10+	E3	9	5	1	5	E1	1	5	7	5	0.22
10	Mech. Eng.	10+	E3	5	3	1	9	E4	5	3	9	1	0.22

Table 6. Pairwise comparison ratings of institutional barriers provided by the engineers.

	Specialty	Experience	Institutional Barriers										
			BEST	E5	E6	E7	E8	WORST	E5	E6	E7	E8	CR^I
1	Architect	10+	E6	3	1	9	5	E7	5	9	1	5	0.22
2	Civil Eng.	5–10	E6	7	1	3	3	E5	1	3	3	3	0.10
3	Civil Eng.	5–10	E5	1	1	3	7	E8	7	5	5	1	0.19
4	Civil Eng.	10+	E6	1	1	3	1	E7	3	3	1	3	0
5	Civil Eng.	10+	E8	9	5	9	1	E5	1	3	1	9	0.08
6	Civil Eng.	5–10	E5	1	7	3	5	E6	9	1	3	3	0.19
7	Civil Eng.	5–10	E6	5	1	5	9	E8	5	9	5	1	0.22
8	Civil Eng.	10+	E5	1	9	3	7	E6	9	1	7	3	0.17
9	Mech. Eng.	10+	E5	1	7	9	7	E7	7	3	1	3	0.17
10	Mech. Eng.	10+	E7	9	5	1	5	E5	1	3	7	5	0.22

Table 7. Pairwise comparison ratings of professional and social barriers provided by the engineers.

	Specialty	Experience	Professional and Social Barriers														
			BEST	E9	E10	E11	E12	E13	E14	WORST	E9	E10	E11	E12	E13	E14	CR^I
1	Architect	10+	E14	5	7	5	9	1	1	E12	5	3	5	1	9	9	0.22
2	Civil Eng.	5–10	E13	3	3	5	3	1	3	E11	3	3	1	3	3	3	0.2
3	Civil Eng.	5–10	E14	1	3	3	5	1	1	E12	5	1	3	1	5	7	0.2
4	Civil Eng.	10+	E14	1	1	7	3	1	1	E11	7	5	1	5	3	5	0.19
5	Civil Eng.	10+	E12	5	5	5	1	9	9	E13	5	5	5	9	1	1	0.22
6	Civil Eng.	5–10	E10	1	1	1	3	7	5	E13	9	9	7	3	1	3	0.10
7	Civil Eng.	5–10	E10	5	1	5	5	9	5	E13	5	9	5	5	1	5	0.22
8	Civil Eng.	10+	E13	7	9	5	5	1	5	E10	3	1	5	5	9	5	0.22
9	Mech. Eng.	10+	E10	9	1	7	7	7	7	E9	1	9	3	3	3	3	0.16
10	Mech. Eng.	10+	E10	9	1	5	7	7	9	E14	3	9	3	3	3	1	0.25

Table 8. Pairwise comparison ratings of market and technological barriers provided by the engineers.

	Specialty	Experience	Market Barriers								CR^I	Tech. Barriers		
			BEST	E15	E16	E17	WORST	E15	E16	E17		BEST	E18	E19
1	Architectural	10+	E16	9	1	5	E15	1	7	3	0.08	E19	7	1
2	Civil Eng.	5–10	E17	7	3	1	E15	1	3	3	0.10	E18	1	3
3	Civil Eng.	5–10	E17	7	3	1	E15	1	3	7	0.05	E19	5	1
4	Civil Eng.	10+	E17	5	3	1	E15	1	1	3	0.10	E18	1	7
5	Civil Eng.	10+	E15	1	9	9	E17	9	1	1	0	E19	1	1
6	Civil Eng.	5–10	E17	3	3	1	E16	1	1	3	0	E19	7	1
7	Civil Eng.	5–10	E16	9	1	3	E15	1	9	5	0.08	E19	5	1
8	Civil Eng.	10+	E17	7	3	1	E15	1	3	9	0.048	E19	5	1
9	Mechanical Eng.	10+	E17	5	9	1	E16	3	1	9	0.08	E19	5	1
10	Mechanical Eng.	10+	E15	1	5	9	E17	5	3	1	0.08	E18	1	5

Following this conversion process, these values were then used in the BWM solve-linear version-Excel file, as provided by the developer of the method, Rezaei (2016), to calculate the weights for the categories and the partial barrier scores per category for each respondent. Table 9 shows the resulting weights for each category by each engineer and the average result for all engineers. Similarly, Tables 10–12 present the resulting partial scores for each barrier per category and per engineer and the resulting average score.

Table 9. Category weights provided by the engineers.

	Specialty	Experience	Categories of Barriers				
			K1	K2	K3	K4	K5
1	Architectural	10+	0.574	0.099	0.138	0.138	0.051
2	Civil Eng.	5–10	0.341	0.341	0.129	0.059	0.129
3	Civil Eng.	5–10	0.170	0.396	0.094	0.170	0.170
4	Civil Eng.	10+	0.282	0.128	0.333	0.077	0.179
5	Civil Eng.	10+	0.544	0.094	0.220	0.048	0.094
6	Civil Eng.	5–10	0.660	0.062	0.109	0.085	0.085
7	Civil Eng.	5–10	0.049	0.552	0.133	0.133	0.133
8	Civil Eng.	10+	0.544	0.220	0.094	0.048	0.094
9	Mechanical Eng.	10+	0.590	0.108	0.108	0.084	0.108
10	Mechanical Eng.	10+	0.525	0.091	0.127	0.212	0.046
		Sum:	4.280	2.092	1.486	1.053	1.090
		Average:	0.428	0.209	0.149	0.105	0.109

Table 10. Resulting economic and institutional barriers scores provided by the engineers.

	Specialty	Experience	Economic Barriers				Institutional Barriers			
			E1	E2	E3	E4	E5	E6	E7	E8
1	Architectural	10+	0.144	0.078	0.144	0.633	0.232	0.578	0.051	0.139
2	Civil Eng.	5–10	0.375	0.125	0.375	0.125	0.094	0.469	0.219	0.219
3	Civil Eng.	5–10	0.375	0.094	0.375	0.156	0.431	0.345	0.172	0.052
4	Civil Eng.	10+	0.184	0.079	0.553	0.184	0.300	0.300	0.100	0.300
5	Civil Eng.	10+	0.401	0.458	0.092	0.049	0.070	0.151	0.084	0.695
6	Civil Eng.	5–10	0.065	0.109	0.674	0.152	0.578	0.071	0.220	0.132
7	Civil Eng.	5–10	0.637	0.056	0.153	0.153	0.153	0.637	0.153	0.056
8	Civil Eng.	10+	0.159	0.065	0.688	0.088	0.601	0.053	0.242	0.104
9	Mechanical Eng.	10+	0.065	0.157	0.620	0.157	0.688	0.116	0.080	0.116
10	Mechanical Eng.	10+	0.139	0.232	0.578	0.051	0.065	0.157	0.620	0.157
		Sum:	2.545	1.452	4.252	1.750	3.211	2.877	1.942	1.970
		Average:	0.255	0.145	0.425	0.175	0.321	0.288	0.194	0.197

Table 11. Resulting professional and social barriers scores provided by the engineers.

	Specialty	Experience	Professional and Social Barriers					
			E9	**E10**	**E11**	**E12**	**E13**	**E14**
1	Architectural	10+	0.088	0.063	0.088	0.032	0.365	0.365
2	Civil Eng.	5–10	0.145	0.145	0.081	0.145	0.339	0.145
3	Civil Eng.	5–10	0.220	0.051	0.096	0.058	0.288	0.288
4	Civil Eng.	10+	0.233	0.233	0.033	0.100	0.167	0.233
5	Civil Eng.	10+	0.124	0.124	0.124	0.514	0.046	0.069
6	Civil Eng.	5–10	0.258	0.295	0.258	0.098	0.032	0.059
7	Civil Eng.	5–10	0.117	0.488	0.117	0.117	0.043	0.117
8	Civil Eng.	10+	0.087	0.045	0.121	0.121	0.505	0.121
9	Mechanical Eng.	10+	0.056	0.574	0.093	0.093	0.093	0.093
10	Mechanical Eng.	10+	0.072	0.561	0.129	0.092	0.092	0.053
		Sum:	1.400	2.578	1.140	1.371	1.968	1.543
		Average:	0.140	0.258	0.114	0.137	0.197	0.154

Table 12. Resulting market and technological barriers scores provided by the engineers.

	Specialty	Experience	Market Barriers			Technological Barriers	
			E15	**E16**	**E17**	**E18**	**E19**
1	Architectural	10+	0.091	0.740	0.169	0.125	0.875
2	Civil Eng.	5–10	0.120	0.280	0.600	0.750	0.250
3	Civil Eng.	5–10	0.120	0.280	0.600	0.167	0.833
4	Civil Eng.	10+	0.150	0.250	0.600	0.875	0.125
5	Civil Eng.	10+	0.818	0.091	0.091	0.500	0.500
6	Civil Eng.	5–10	0.200	0.200	0.600	0.125	0.875
7	Civil Eng.	5–10	0.067	0.680	0.253	0.167	0.833
8	Civil Eng.	10+	0.083	0.250	0.667	0.167	0.833
9	Mechanical Eng.	10+	0.165	0.077	0.758	0.167	0.833
10	Mechanical Eng.	10+	0.714	0.184	0.102	0.833	0.167
		Sum:	2.528	3.032	4.440	3.875	6.125
		Average:	0.253	0.303	0.444	0.388	0.613

Finally, to calculate the total score for each barrier so that they could be ranked based on their significance, each barrier's partial score was multiplied by the weight of its category. For example, barrier E5, insufficient incentives, was calculated to have an average score of 0.321 (Table 10). Its category, K2, institutional barriers, has a weight of 0.209 (Table 9). Therefore, the final significance score for barrier E5, insufficient incentives, is 0.321 × 0.209 = 0.067 or 6.7%. Table 13 shows the final significance score of the barriers according to the aggregate opinions of the 10 engineers.

Table 13. Final overall significance scores per barrier provided by the engineers.

Category	Barriers		Barrier Scores	Category Weights	Final Barrier Score
Economic Barriers	E1	High initial cost	0.255	0.428	0.109
	E2	Low rate of return on investment, low profitability	0.145	0.428	0.062
	E3	Lack of funds and difficulty in securing loans	0.425	0.428	0.182
	E4	High final and maintenance costs	0.175	0.428	0.075
Institutional Barriers	E5	Insufficient incentives	0.321	0.209	0.067
	E6	Lack of guidelines, instructions and evaluation standards	0.288	0.209	0.060
	E7	Weak political will. Different priorities	0.194	0.209	0.041
	E8	Absence of a proper building database	0.197	0.209	0.041

Table 13. *Cont.*

Category		Barriers	Barrier Scores	Category Weights	Final Barrier Score
Professional and Social Barriers	E9	Inexperienced and unskilled professionals	0.140	0.149	0.021
	E10	Low awareness and lack of information	0.258	0.149	0.038
	E11	Fear of failure. Doubt about achieving desired goals	0.114	0.149	0.017
	E12	Prejudice against new practices	0.137	0.149	0.020
	E13	Delays in work schedule	0.197	0.149	0.029
	E14	Cooperation between different employee groups	0.154	0.149	0.023
Market Barriers	E15	Doubt about the demand for the products	0.253	0.105	0.027
	E16	Building materials (availability, cost, durability, reliability)	0.303	0.105	0.032
	E17	Insufficient public information and promotion of materials	0.444	0.105	0.047
Technological Barriers	E18	Incompatible technology. Slow development	0.388	0.109	0.042
	E19	Absence of exhibitions promoting new technologies	0.613	0.109	0.067

The same procedure as above was carried out for the other two categories of respondents (skilled workers and owners, resulting in Table 14, which shows the top 10 barriers in each group ranking, as well as the barriers with the highest frequency of occurrence in the literature survey).

Table 14. Ranking of barriers in terms of significance (top 10 barriers).

	Engineers			Skilled Workers			Owners			Literature (Table 1)		
		Barriers	Final Score		Barriers	Final Score		Barriers	Final Score		Barriers	No.
1	E3	Lack of funds and difficulty in securing loans.	18.20	E1	High initial cost.	13.29	E1	High initial cost.	15.49	E6	Lack of guidelines, instructions and evaluation standards.	28
2	E1	High initial cost.	10.89	E4	High final and maintenance costs	12.68	E3	Lack of funds and difficulty in securing loans.	11.26	E7	Weak political will. Different priorities.	26
3	E4	High final and maintenance costs	7.49	E3	Lack of funds and difficulty in securing loans.	12.26	E4	High final and maintenance costs	8.48	E10	Low awareness and need for more information.	25
4	E5	Insufficient incentives.	6.72	E19	Absence of exhibitions promoting new technologies.	7.77	E2	Low rate of return on investment, low profitability.	6.58	E5	Insufficient incentives.	23
5	E19	Absence of exhibitions promoting new technologies.	6.68	E18	Incompatible technology. Slow development.	6.42	E18	Incompatible technology. Slow development.	5.80	E9	Inexperienced and unskilled professionals.	21
6	E2	Low rate of return on investment, low profitability.	6.22	E16	Building materials (availability, cost, durability, reliability)	5.63	E16	Building materials (availability, cost, durability, reliability)	5.55	E1	High initial cost.	18
7	E6	Lack of guidelines, instructions and evaluation standards.	6.02	E17	Insufficient public information and promotion of materials.	5.27	E17	Insufficient public information and promotion of materials.	5.04	E4	High final and maintenance costs	18

Table 14. *Cont.*

	Engineers			Skilled Workers			Owners			Literature (Table 1)	
		Barriers	**Final Score**		**Barriers**	**Final Score**		**Barriers**	**Final Score**	**Barriers**	**No.**
8	E17	Insufficient public information and promotion of materials.	4.67	E9	Inexperienced and unskilled professionals.	4.84	E6	Lack of guidelines, instructions and evaluation standards.	5.01	E16	Building materials (availability, cost, durability, reliability)	18
9	E18	Incompatible technology. Slow development.	4.22	E10	Low awareness and lack of information.	3.92	E5	Insufficient incentives.	4.84	E2	Low rate of return on investment, low profitability.	17
10	E8	Absence of a proper building database.	4.12	E2	Low rate of return on investment, low profitability.	3.84	E8	Absence of a proper building database.	4.31	E17	Insufficient public information and promotion of materials.	17

5. Discussion

According to the survey results, financial barriers are the most significant for the EUoB. All group results show that the top three barriers, E1, E2, and E4, are related to costs, i.e., high initial costs, a lack of funds, and high final and maintenance costs. This is an expected result because of the country's financial situation, as described in Section 3.1. An interesting observation is that the barrier in fourth place is different in each category. The homeowners and the engineers are consistently concerned with economic barriers, and therefore the homeowners rate the low rate of return on their investment as the fourth most important barrier, while the engineers support this opinion. Finally, in contrast with the other two categories, the skilled workers believe that two technological barriers, incompatible technology (E18) and the absence of exhibitions promoting new technologies (E19), are the next two most significant barriers. It is also noteworthy that the other two categories of respondents place these barriers in fifth place. When comparing these findings to the research carried out in the international literature, it can be observed that in other countries, institutional barriers and a lack of public awareness appear more often, followed by economic barriers. A common feature is that in both the literature review and in the current survey, the need for proper skills among professionals in the field is pointed out.

It is noteworthy that it was easier to explain the required pairwise comparison process to people who had higher levels of academic education. Despite the use of a smaller scale (1–5 instead of 1–9) in the questionnaire and the presence of the researcher during the completion of the questionnaire by the skilled workers and homeowners, challenges were encountered. A high degree of inconsistency was observed in the responses of the 10 homeowners who completed the questionnaire without the presence of the researcher. On the contrary, there was no difficulty in understanding or incorrect completion of the questionnaire on the part of the engineers.

Consequently, although it was essential to record the homeowners' opinions on the barriers they have faced or that prevent them from upgrading the energy performance of their property, it was understood that a very large sample was not necessary. Therefore, the qualitative characteristics of the individuals (educational level) were the most crucial factor.

As far as MCDM methods are concerned, the BWM is more direct than other similar methods, such as AHP. An initial comparison between the alternatives is carried out "unconsciously", selecting the best and the worst. Pairwise comparisons are then made using these initial choices as a measure. In contrast, in AHP, many more comparisons are made, which may result in more errors in the consistency of the answers. Nevertheless, like other MCDM methods, it has limitations in its application to more complex decision-making problems that could lead to misleading conclusions. For example, in the homeowners' responses, the barrier (E18) "Incompatible technology, slow development" had a weighting factor of 0.609, and the group/category in which it is located, "Technological barriers" (K5), had a weighting factor of 0.095. The final significance rate of barrier E18 was calculated as 0.609 × 0.095 = 0.058 or 5.8%. As can be seen in this example, despite the fact that the category in which the barrier is located (K5) was given a low weighting rate, the barrier was ranked high because, in this category, there were only two alternatives (barriers) that had a cumulative weighting rate of E18 + E19 = 1.

6. Conclusions

According to these results, all three groups (engineers, skilled workers, and homeowners) consider economic barriers more critical. More specifically, high initial costs, a lack of funds, difficulty in securing loans, and high final and maintenance costs were ranked in the first positions. Despite the efforts of governments to promote energy upgrades through economic programs, this survey reflects that economic concerns persist. An essential factor in this is the economic crisis in recent decades, which has significantly reduced the incomes of citizens, and the energy crisis, which has significantly increased the cost of energy. Also, the lack of public information and promotion of materials was ranked high by both skilled workers and homeowners, indicating a need for better training so that workers can be adept in these new skills and better information can be made available to homeowners.

The results of this study show that it is vital to inform the public about the economic benefits of energy upgrades through reduced energy consumption and to promote green materials, which are wrongly perceived by many as expensive. Therefore, governments should take the importance of fully informing the public about all aspects of energy upgrading seriously, instead of just providing financial incentives. It is also necessary to understand that investment in energy upgrading will yield not only economic benefits but also an improvement in the quality of life within energy-upgraded buildings. Furthermore, the financial incentive programs (Exoikonomo) would be more effective if they were targeted at a more significant proportion of citizens. The income criteria that exist discourage families with incomes higher than the predefined incomes of the programs.

The skilled workers report that they need to be sufficiently trained to carry out such work. Furthermore, according to their responses, they need more confidence in new materials and practices to engage in energy retrofitting work. The above issue indicates how important it is to train professionals in the field through seminars to familiarize them with new techniques and materials.

The ranking of barriers to the EUoB was chosen to be carried out using the BWM, an MCDM method. As mentioned above, these methods also have limitations. For example, if a questionnaire had been created to assess the barriers on a scale of 1 to 5, without creating categories and without comparing them with each other, another method of analyzing results, such as the Relative Importance Index or descriptive statistics, could have been chosen. Using the BWM is feasible only if the elements to be compared are less than or equal to 9. As a result, to apply the method, the barriers needed to be split into categories, resulting in categories with more and others with fewer alternatives to be compared. Consequently, the final scores were affected. As noted, the five point rating scale used to facilitate responses from the participants neglected the intermediate values (2, 4, 6, 8). As a result, another limitation of this study is the possible loss of data that, if they had been captured, may have resulted in more distinct differences in the final rankings or better resulting consistency ratios. Finally, another limitation stemming from the chosen method is that the survey had a limited number of respondents because it was considered necessary to have the questionnaire completed in the presence of the researcher for the participant to understand the pairwise comparison process better. Therefore, since the BWM cannot map relationships among barriers, further research should be carried out based on a larger dataset and using other statistical methods such as the F-DEMATEL method employed by Yadav et al. [70] in parallel with the BWM for prioritizing enablers in the manufacturing supply chain in India or factor analysis used by Antoniou et al. [71] to determine relationships between construction contract type selection criteria.

For other future research directions, it would be beneficial to evaluate the success of the incentive programs that have been and are still being implemented. Creating a reliable database with all the characteristics of the economic programs and the energy upgrades carried out through them would make it possible to identify areas for improvement. In addition, conducting a similar survey on a larger scale and in combination with MDCM methods and Geographic Information Systems (GIS) will provide a better view of the whole territory. This would make it possible to better identify the problems encountered in each region of the country.

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