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Research article

Heterogeneous or homogeneous? A modified decision-making approach in renewable energy investment projects

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Abstract: The continuous increase of energy consumption resulted in the unavoidable increase in demand for renewable energy (RE) investment projects in recent years. Although the necessity of developing alternative energy sources is clear, the government cannot afford the huge investment in RE investment projects without private sector participation. Therefore, analyzing the decision-making procedure from the investor's point of view is essential to improve this process. Numerous studies in the literature developed various multi-criteria decision-making approaches using expert's judgments to provide informed decisions on RE investment projects. While prior efforts are valuable, accounting heterogeneity impact with regard to experts' background and knowledge on results has not been examined. Therefore, this study aims to develop a modified decision-making approach in RE projects using an analytical hierarchy process to: (1) provide a comprehensive review of investors criteria in RE projects; (2) evaluate how the level of expertise of experts in RE subject has an impact on the achieved common solution; and (3) determine the best RE alternative in different scenarios. Then, Iran, as a case study is selected to illustrate the model practicability. The results indicate that those who have higher expertise in the subject are more concerned about the "consumption market", and "government supportive policies". Whereas economic factors remain the most challenging criteria in less expert participation views. Both groups chose 'wind energy' as the best alternative energy source for investment based on current Iran's energy market. It is anticipated that the developed methodology and its results can be used by (1) government and public agencies to understand the investors' concerns; (2) investors to make a more-informed risk-based decision in RE projects or other complex decision-making projects.

Keywords: renewable energy; decision making; heterogeneity; analytical hierarchy process

1. Introduction

The energy sector picture has changed in the past few decades by shifting the focus from fossil energy resources to renewable energy (RE) alternatives all around the world [1–4]. The reason behind this global shift pattern could be explained by two main motivations. First, numerous studies highlighted environmental concerns such as climate change [5–7], greenhouse gas emission [8,9], air pollution, and soil and water contaminations [10]. Second, it is clear that traditional fossil fuels are finite energy sources [11]. Additionally, the emerging concept of circular economy (CE) is considered recently within sustainable development [12]. The CE economic business models emphasize replacing the “end-of-life” concept with reusing and recycling [13,14]. However, the International Energy Agency (IEA) [15] reports that around 7% of the global generated electricity is associated with RE sources excluding large hydropower plants in 2018. Therefore, there is a long path to complete full energy transition to renewable sources and the current transition speed is insufficient [16,17].

Although individual countries’ strategies and plans to fulfill this energy transition are different, governments understand that huge investment in RE projects without private sector participation is impossible [18]. Accordingly, multiple investment incentives (low-interest rate, guaranteed purchase price) [19], tax incentives (accelerated depreciation opportunities) [20], and tariff incentives (feed-in tariffs) [21] are shaped to attract more private investors. Various available RE technologies make investors’ decisions more difficult considering the complex and dynamic energy market conditions [22]. Therefore, providing an informed-decision making process to investors is one of the most essential elements of improving private sector participation in RE projects.

Literature frequently highlights group decision making (GDM) techniques to solve a complex decision-making process [23,24]. Most GDM techniques rely on experts’ judgment to achieve a common solution. Therefore, the heterogeneity of experts by considering their background, point of view, and level of expertise in the subject is influential on the achieved results [25]. There are two main approaches in the GDM process containing consensus-reaching and aggregation processes in the literature [26]. The consensus-reaching depends on group discussion and negotiation to reach an agreement as opposed to the aggregation process approach in which experts provide their opinions individually and the final result is aggregated considering all the opinions together [26]. Researchers criticize the consensus-reaching approach because of the intensive time and resources requirement. On the other hand, it may possible that a stronger voice in the group, because of powerful positions or experienced professionals, influences other opinions [25]. Therefore, literature places more emphasis on the importance of participation’s personality in the consensus-reaching approach to reach a better result [27]. In contrast, in the aggregation process approach, the heterogeneity or homogeneity of the experts is the point that raised concerns [28]. There are numerous studies in the literature utilizing GDM techniques to analyze decision making in RE projects [29,30] and improve this process. While prior efforts are valuable, accounting heterogeneity impact with regard to experts’ background and knowledge on results has not been examined. To address this question, this study suggests a modified decision-making approach considering the level of experts’ expertise. The main contribution of the paper is as follows: (1) introduce a clear list of investors criteria in RE investment projects (2) develop a systematic decision-making model which relies on a modified analytical hierarchy process (AHP) (3) evaluate the impact of expertise level in the RE subject on GDM results.

The rest of the paper is structured as follows: first, a literature review of different approaches in RE decision making and their result is provided. Next, a modified AHP model is presented to consider the expertise level in RE subject to find the investors' concerns as well as the best RE alternative source based on the current energy market situation. Finally, the conclusion and research direction for future studies is discussed.

2. Literature review

Renewable energy sources typically are considered as solar, biomass, wind, geothermal, and hydropower categories [31]. Various studies report the technical advancement in renewable energy technologies which resulted in a considerable efficiency improvement in recent years [32–35]. On the other hand, numerous studies evaluate the basic renewable energy requirements such as solar radiation [36], wind speed potential [37,38], site location, and geotechnical issues [39–41]. With all this in mind, selecting one of these categories for investment is a critical question in the investor's view. This study attempts to answer this question by considering multiple scenarios using a modified group decision-making (GDM) approach.

As discussed, GDM techniques are very common to utilize for analyzing complex decision-making processes in the literature among various research domains [42,43]. RE investment projects due to the involvement of multiple technical, governmental, social, economic, and environmental aspects are complex [44]. Therefore, GDM techniques solve this complexity and help decision-making from investors' point of view or evaluate the energy policies [45]. Generally, GDM studies can be classified into two main groups including consensus-reaching and aggregation process groups. In the consensus-reaching approach, the result is based on a group discussion. A revised version that has been employed in the literature is a Delphi method [46]. Kul et al. [47] applied Delphi techniques in renewable energy risk assessment. In this approach, after receiving the first evaluation and opinion of experts, they will be informed of the other overall opinions and asked to modify their first comments [47]. The only concern about this approach is still the possibility of being time-consuming [48]. On the other hand, the aggregation process approach is much more attractive for researchers. Many studies relied on AHP and analytic network process (ANP) to evaluate the importance of decision-making criteria, energy policies, or renewable project type selection [49].

From early studies, Aslani et al. [50] investigate the decision-making criteria for renewable energy investment projects in Iran using AHP. They classify criteria into three main categories including 'technical', 'business and policies', and 'environment'. The technical group includes 'engineering efficiency', 'annual exploitability', and 'regional energy potential'. 'Finance', 'consumption market', and 'government policies' are considered in the business and policies category. Last, the 'energy payback ratio' is recognized as a sub-criteria in the environment category. Among these sub-criteria, 'government policies' was selected as the most important factor. In 2014, Aslani and Wang [51], in a similar study using AHP compared different energy alternatives for investment in Iran. Their findings showed solar and wind sources respectively ranked first and second for investment at that point. Reviewing potential decision-making criteria are discussed in detailed in literature [52]. In Baron's [53] study, the importance weight of decision-making criteria in the RE project and the best energy alternative for Turkey were evaluated. The established framework was based on using AHP to determine the weight of sub-criteria. In a recent study, Alizadeh et al. 2020 introduce a combined benefit, cost and risk model using ANP relying on expert judgment for decision making in RE projects [29].

Moreover, Ozorhon et al. [54] made a comprehensive review of decision-making criteria in RE projects. 23 sub-criteria under three main groups of 'technical', 'economic', and 'environmental and social' were investigated in their study. Their finding illustrates the important role of government based on policies and regulations to attract private investors. Among the literature, studies not only follow different criteria break down structures, but also missed evaluating experts' heterogeneity and their influential impact on the result. How are those with higher experience, knowledge, and background in this topic thinking differently from experts with less expertise? Therefore, this study aims is to answer this question and provide a modified decision-making approach to consider different scenarios of a heterogeneous group of experts' involvements.

3. Research methodology

The main objective of this paper is to propose a modified decision-making framework for renewable energy investment projects. As discussed before, the developed framework considers the complex environment of these projects due to the recent rapid growth and economic changes.

The structure of the proposed decision-making framework consists of two main stages with unique steps. The first stage is "Criteria identification". It includes a comprehensive identification of various criteria affecting RE investment projects. The second stage is a "Modified AHP model". The main advantage of this modified model considers the level of expertise and experience of RE experts. Finally, the last part of this research identifies those criteria that have more impact on the decision-making process and compare the result in the modified and unmodified scenarios. Figure 1 exhibits the overall process of the proposed framework.

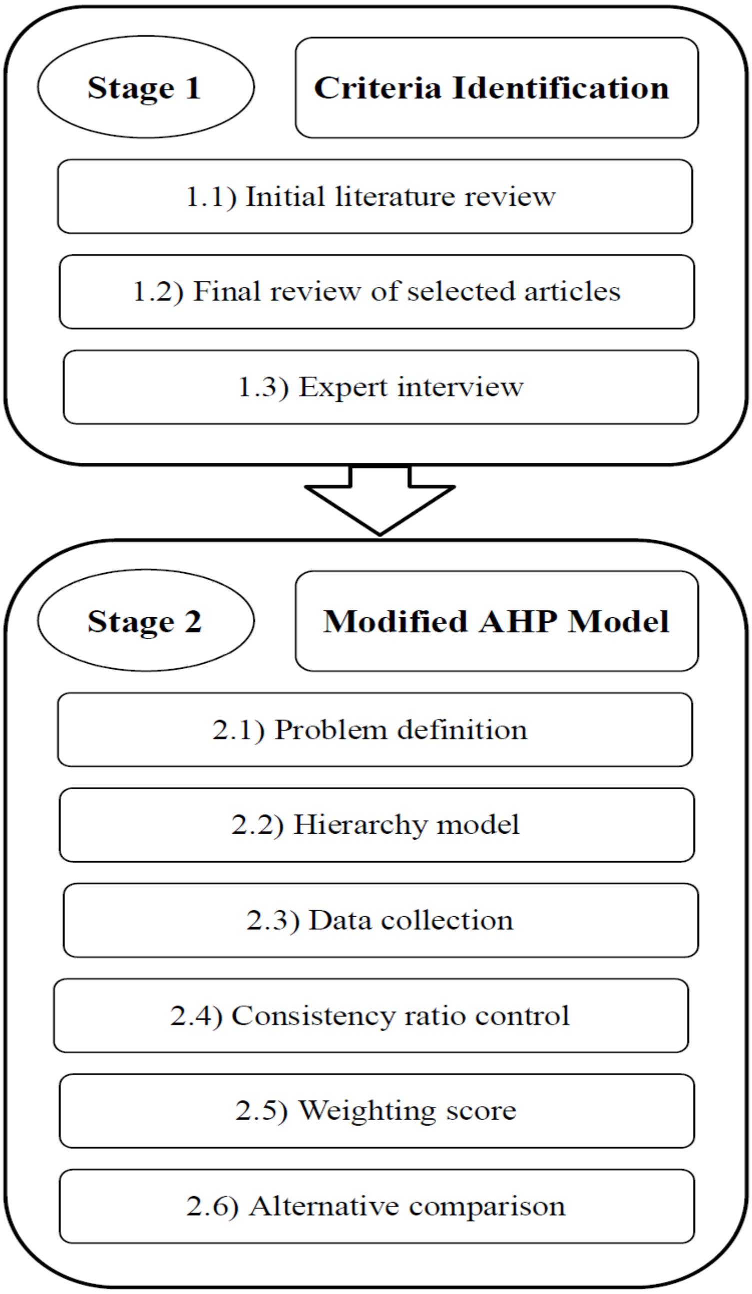

Figure 1. Structure of the developed decision-making framework.

3.1. Criteria identification

3.1.1. Initial literature review

A systematic literature review is conducted based on previous studies that identify the decision-making criteria in RE projects. The selected keywords for review include "Decision making", "Multi-criteria decision making", "Renewable energy", and "Investment". The papers are searched in the database includes Google scholar and Taylor & Francis Online.

3.1.2. Final review of selected articles

86 identified papers in the initial review are examined based on the following criteria: (a) the paper implied RE investment decision making criteria (b) the paper was published in a Peer-reviewed journal. Finally, 15 papers among the identified papers are selected for a full review. Based on the final literature review, 4 criteria and 13 indexes are identified. The 'Technical' criteria include 'Annual exploitability', 'Energy efficiency', 'Level of construction and operation difficulties', 'Reliability of technology', and 'Safety' indexes. The 'Economic' criteria consist of indexes including 'Investment cost', 'Operation and maintenance cost', and 'Consumption market'. Also, the 'Social and Governmental' criteria include 'Social benefits', and 'conformity with supportive policies of government'. Finally, the 'Environmental' criteria include 'CO_2 emission rate', 'Noise', 'Land-use', and 'visual impact'. The initial identification demonstrates how various aspects of technical, economic, and environmental influence the decision making in these projects.

3.1.3. Expert interview

Three semi-structured interviews are conducted at this step to finalize the list of decision-making criteria. The experts include one project manager, one avid researcher, and one active investor with rich experience in RE projects. They are asked to evaluate the identified criteria based on the condition of investing in RE projects in Iran. All experts agreed to merge the 'CO_2 emission rate', 'Noise', 'Land-use', and 'visual impact' in one index and renamed it to 'Effects on the natural environment'. Therefore, the final list of identified decision-making criteria is prepared.

Table 1 summarizes the identified indexes and associated sources.

Table 1. Decision making criteria identification.

Criteria	Index	[55]	[56]	[57]	[50]	[51]	[58]	[59]	[60]	[61]	[62]	[54]	[63]	[64]	[65]	[66]
Technical	**C1:** Annual Exploitability				✓	✓	✓	✓	✓		✓	✓	✓	✓		✓
	C2: Energy Efficiency		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
	C3: Level of Construction and Operation Difficulties										✓	✓				
	C4: Reliability of Technology	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓		
	C5: Safety		✓	✓			✓		✓			✓				✓
Economic	**C6:** Investment Cost	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	C7: Operation and Maintenance Cost	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓
	C8: Consumption Market				✓	✓			✓				✓			
Social & Governmental	**C9:** Social Benefits	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	C10: Conformity with Supportive Policies of Government				✓	✓			✓		✓			✓		
Environmental	**C11:** Effects on natural Environment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

3.2. Modified AHP

3.2.1. Problem definition

The ultimate goal of this research is to provide a modified decision-making approach in RE projects. For this purpose, a weighting system is introduced to compare different experts' knowledge in the topic of decision making which provides the possibility to consider the competency of experts in the RE field to analyze the process in different scenarios.

3.2.2. Hierarchy model

A hierarchy structure of the AHP model includes goal, criteria, and indexes which can be compared when they are at the same level [67]. The hierarchy model of our problem is provided based on the result of the stage 1. Figure 2 illustrates the hierarchical structure of this research.

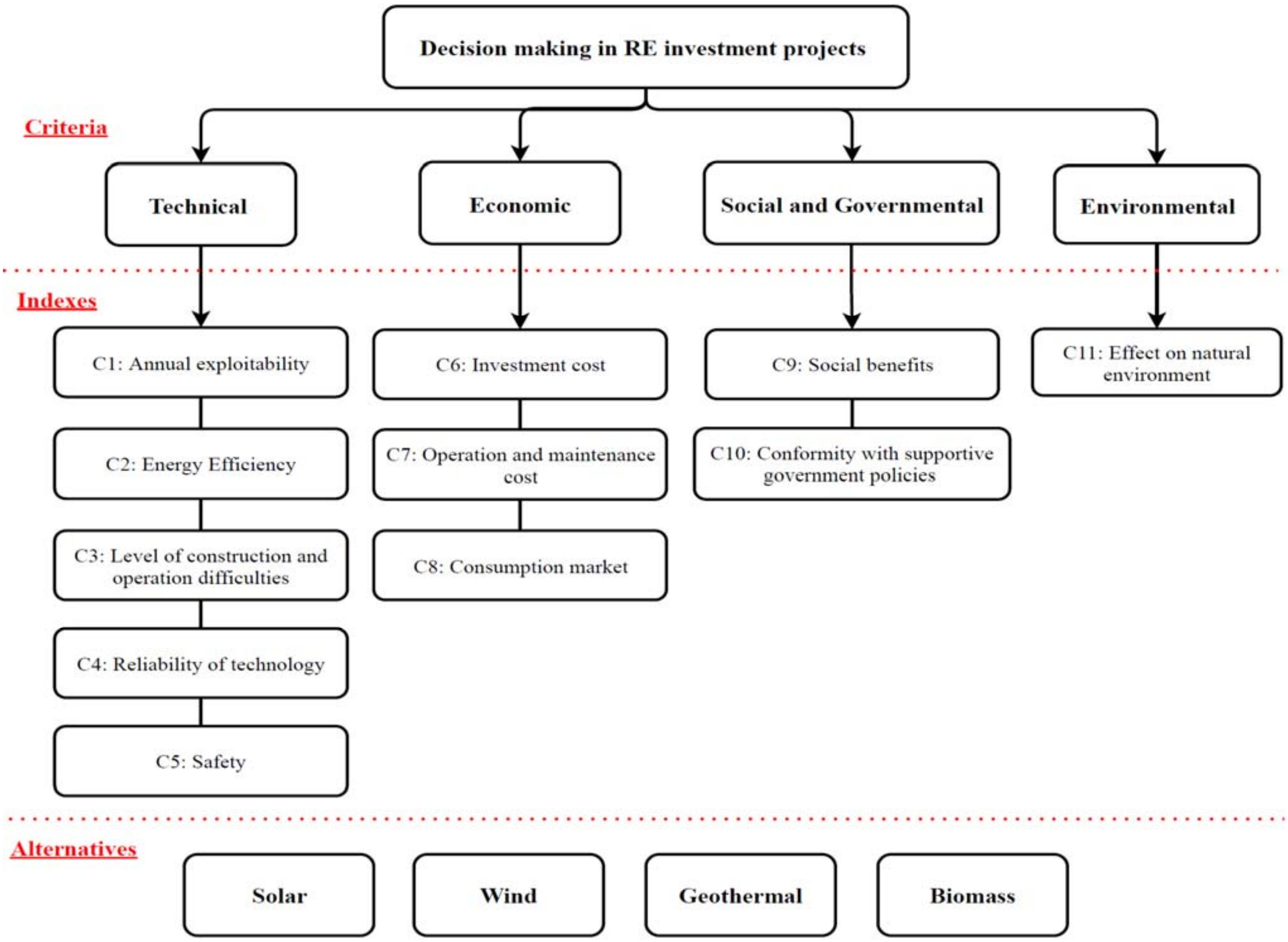

Figure 2. Hierarchy model of decision making in RE investment projects.

3.2.3. Data collection

A questionnaire is developed for the purpose of this research to collect data for the further modified AHP analysis. The survey is designed to ask participants to compare the investment indexes provided in Figure 2 from the investor's perspective and assign the importance weight for alternative energy source selection based on the current energy market. AHP studies only require a smaller group of responders [68] due to the inherent characteristics of this approach. In order to select a random sample of experts who has various expertise and background in this topic, the following procedure is completed to guarantee a reliable result.

First, a list of top companies that frequently work in renewable energy investment projects in Iran is gathered. Then, executive members and project managers' information for each company is collected by checking their online websites, resulting in a list including 200 persons. The next step is to randomly select 50 members of this list to participate in our analysis. Among those 50 persons that received our questionnaire, 20 experts provide their detailed responses. The responders are asked to provide a pairwise comparison between identified indexes on a nine-point scale [67]. The nine-point scale provided in Table 2 is used to translate the expert judgment into numerical values. A judgmental matrix (A) is developed for each responder that a_{ij} member shows the comparison between index i to index j.

Table 2. The AHP pairwise comparison scale [69].

Intensity of importance	Definition	Explanation
1	Equal importance of both index	Equal contribution to the objective from both index
3	Moderate importance I over J	Slightly favored one index over another
5	Strong importance I over J	Strongly favored one index over another
7	Very strong importance I over J	Very strongly favored on index over another
9	Absolute importance	One index over another is of the highest possible order affirmation
2,4,6,8	Intermediate values between two Adjacent scale values	Represent compromise between the priorities listed above

3.2.4. Consistency ratio control

As the AHP approach includes various pairwise comparisons from each responder between multiple indexes, to check the consistency of responses a consistency ratio (CR) is calculated [70]. The CR is calculated in this step based on the Eq 1. Based on [70] CR set as 0.1 using a nine-point scale. And if the CR is less than 0.1, the responses are valid and acceptable.

$$\text{Consistency ratio (CR)} = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)} \quad (1)$$

where:

$$\text{CI}= \frac{\lambda_{max}-1}{n-1} \quad (2)$$

λ_{max} = approximation of the maximum eigenvalue, n = number of elements of comparison.

3.2.5. Weighting score

As discussed in the literature review, the main point that raised concerns in the AHP approach is the heterogeneity of experts involved in the study. Therefore, experts that have more experience, background, and knowledge in the topic may have different concerns and opinions from those with less experience. On the other hand, it is better to maintain the diversity to compare different opinions on the topic. Accordingly, this study attempts to introduce a modified method to capture both needs. The modified model is based on considering weights for the level of expertise of responders in the topic. The first time, [25] raised this concern and emphasized the impact of heterogeneity on the model output. They provide a list of factors that experts' knowledge could be compared based on an AHP model to determine the weight of each factor. They identified factors including "Academic knowledge" (AK), "Experience" (EX), "Professional Performance" (PP), "Project management practice" (PM) which are used in this study [25]. Based on their model result, the weight for each factor is considered in the Eq 3 to define the score of expertise for each participant in our study.

$$\text{Score} = (0.26 \times AK) + (0.17 \times EX) + (0.22 \times PP) + (0.36 \times PM) \quad (3)$$

At the beginning of the questionnaire, multiple questions are designed to evaluate the responders' background and expertise. The score of each section is calculated based on the expert' responses (Appendix). Then, the weight of each expert's response is calculated based on the proportion of expert's score to overall as follows. The modified AHP analysis is performed based on a weighted judgment matrix for each expert. In this way, those experts with higher expertise and background in the topic affect the final result more than fewer expertise responders. On the other hand, a sensitivity analysis will be performed to evaluate how the modified model's result is different from the unmodified model. Eq 4 defines the formula to obtain a weight for each expert response.

$$\text{Weight (expert i)} = \frac{Score_i}{\sum_i^n score} \quad (4)$$

3.2.6. Alternative comparison

In the first part of the analysis, the responders are asked to compare the investment indexes to find the weight of importance among investment criteria in RE projects. This process is performed in two different scenarios of weighted and unmodified models using AHP. The second part includes alternative energy comparison. Different renewable energy scenarios that are typically utilized in Iran including solar, biomass, wind, and geothermal are considered in this study [31]. Due to Iran' geographical location which is in a dry area and recent environmental concerns regarding a large number of dams, hydropower is not considered as one of the energy alternatives in this study [71]. Experts are asked to compare on a pairwise basis for each alternative considering each investment index. The result of this section provides a ranking list of renewable energy sources for investment based on the current energy market.

4. Result: a case study of Iran

As mentioned in section 3.2.2, twenty experts with an acceptable background in the RE projects were selected to participate in this study. The experts are asked to complete the survey considering the Iran energy market. The detailed information about these experts and their answers to intended questions to evaluate their background and expertise is provided in Table 3.

Table 3. Expert participation detailed information.

Expert Number	Academic Knowledge (AK)		Experience (EX)		Professional Performance (PP)		Project Management practice (PM)		SCORE (out of 10)
	educational level	Research background RE	Work Experience	Work Experience in RE	Career positions	Working in last position	work experience	Research experience	
1	Master	×	< 5 years	< 5 years	Executive engineer	<5 years	×	✓	3.31
2	Master	×	10–15 years	10–15 years	Executive engineer Project Manager Consultor Engineer	5–10 years	✓	×	4.65
3	Master	×	> 15 years	< 5 years	Executive engineer Client team	5–10 years	✓	×	4.43
4	Master	✓	< 5 years	< 5 years	Executive engineer	< 5 years	×	×	2.86
5	PhD	✓	> 15 years	> 15 years	Executive engineer Client team	5–10 years	✓	✓	8.68
6	PhD	✓	5–10 years	5–10 years	Consultor Engineer	5–10 years	×	✓	5.69
7	Bachelor	×	< 5 years	< 5 years	Client team	< 5 years	×	×	1.04
8	PhD	✓	> 15 years	> 15 years	Project Manager Site Manager Consultor Engineer	5–10 years	✓	×	7.15
9	Master	×	5–10 years	5-10 years	Executive engineer	5–10 years	✓	×	3.87
10	Master	✓	< 5 years	< 5 years	Executive engineer	< 5 years	×	✓	4.61
11	Bachelor	×	5–10 years	5–10 years	Client team	5–10 years	✓	×	3.35
12	PhD	✓	> 15 years	> 15 years	Executive engineer Project Manager Consultor Engineer	> 15 years	✓	×	7.81
13	Master	×	5–10 years	< 5 years	Executive engineer Consultor Engineer	< 5 years	✓	×	3.70

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Expert Number	Academic Knowledge (AK)		Experience (EX)		Professional Performance (PP)		Project Management practice (PM)		SCORE (out of 10)
	educational level	Research background RE	Work Experience	Work Experience in RE	Career positions	Working in last position	work experience	Research experience	
14	Bachelor	×	> 15 years	5–10 years	Executive engineer Client team Consultor Engineer	< 5 years	✓	×	4.08
15	PhD	✓	5–10 years	5–10 years	Executive engineer Client team	5–10 years	✓	✓	7.66
16	Master	×	> 15 years	> 15 years	Executive engineer	> 15 years	✓	×	5.55
17	Bachelor	×	< 5 years	< 5 years	Executive engineer	< 5 years	✓	×	2.79
18	PhD	✓	10–15 years	10–15 years	Project Manager	5–10 years	✓	✓	7.78
19	Master	×	> 15 years	> 15 years	Executive engineer Project Manager	10–15 years	✓	×	4.77
20	Master	×	5–10 years	5–10 years	Consultor Engineer	5–10 years	×	×	2.12

After receiving the experts' responses, the consistency ratio (CR) as explained is checked. The result shows three respondents' surveys are inconsistent. Therefore, these three cases are removed, and the final weight of each participant is calculated based on the final list of 17 experts. The detailed information about CR values and the final weight of experts are provided in Table 4.

Table 4. Consistency ratio (CR) values and final weight of participants.

Expert number	CR: consistency ratio	CR < 0.10	Final Weight
1	0.13	Not acceptable	-
2	0.05	acceptable	0.054
3	0.2	Not acceptable	-
4	0.09	acceptable	0.033
5	0.06	acceptable	0.101
6	0.05	acceptable	0.066
7	0.07	acceptable	0.012
8	0.07	acceptable	0.083
9	0.06	acceptable	0.045
10	0.04	acceptable	0.054
11	0.09	acceptable	0.039
12	0.06	acceptable	0.091
13	0.05	acceptable	0.043
14	0.06	acceptable	0.047
15	0.06	acceptable	0.089
16	0.06	acceptable	0.065
17	0.06	acceptable	0.032
18	0.08	acceptable	0.090
19	0.07	acceptable	0.055
20	0.14	Not acceptable	-

Expert choice has been used as a reliable and easy-access software to perform AHP analysis for both criteria weighting and CR calculation in the literature [68,72,73]. In two main scenarios including modified AHP (considering weighting for experts) and unmodified model, the indexes' weight and alternatives ranking are provided in Table 5.

Table 5. AHP model result.

Index	Modified weight	Rank	Unmodified weight	Rank
C1: Annual Exploitability	0.036	11	0.038	10
C2: Energy Efficiency	0.068	5	0.064	6
C3: Level of construction and Operation Difficulties	0.059	6	0.069	5
C4: Reliability of Technology	0.051	8	0.059	7
C5: Safety	0.037	10	0.038	10
C6: Investment Cost	0.174	3	0.196	1
C7: Operation and Maintenance Cost	0.102	4	0.112	4
C8: Consumption Market	0.202	1	0.175	2
C9: Social benefits	0.055	7	0.056	8
C10: Conformity with Supportive Government Policies	0.175	2	0.149	3
C11: Effect on Natural environment	0.042	9	0.043	9
SUM	1		1	
Alternative energy source	Modified weight	Rank	Unmodified weight	Rank
Wind	0.361	1	0.348	1
Solar	0.291	2	0.304	2
Geothermal	0.195	3	0.193	3
biomass	0.153	4	0.155	4
SUM	1		1	

Table 5 indicates that those who have higher experience and expertise in the subject are more concerned about 'consumption market', and 'government supportive policies'. Whereas economic factors remained the most challenging criteria in less expert participation views. In terms of alternative energy sources ranking, both groups chose 'wind energy' as the first rank for investment based on current Iran's energy market which has changed significantly in the past few years [37]. A sensitivity analysis will be performed in the next step to evaluate how those who have higher experience and background in the topic think differently from those who have less expertise.

5. Discussion

The main objective of the modified AHP approach is to Evaluate how the level of expertise in the topic affects the final model results may provide useful insights from various angles. The purpose of this section is to summarize the findings of comparing the modified and unmodified AHP models.

1. A sensitivity analysis can be performed to compare the criteria weighting in both modified and unmodified scenarios. First, those who have less expertise in the topic are more concerned about the economic aspects of RE projects. Whereas responders with higher knowledge and experience worry about consumption market and government roles. The sensitivity analysis

indicates the ‘Conformity with Supportive Government Policies’ index has the highest increase of weighting in the modified version. In other words, by increasing the level of expertise in responders this index becomes more important. In contrast, ‘Level of Construction and Operation Difficulties’ is the index that receives less importance in the modified model. The detailed information about the sensitivity analysis result is provided in Figure 3. However, in the alternative selection ranking, both modified and unmodified approaches indicate similar results in which wind energy and solar sources rank first and second respectively. There is slightly more attention to wind energy in the modified model when the level of expertise is considered.

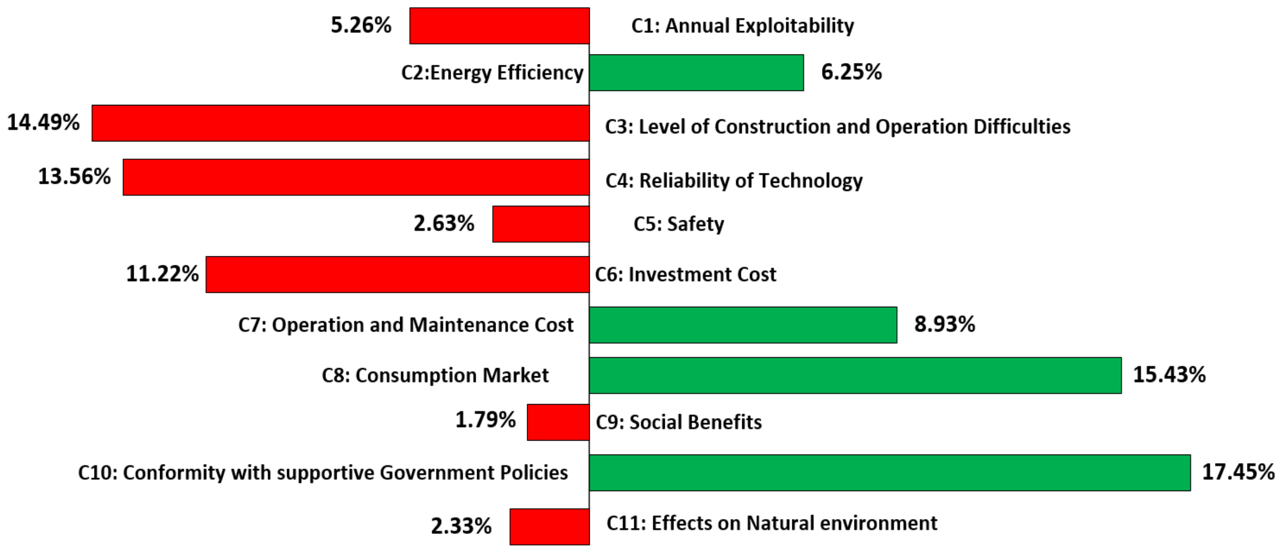

Figure 3. The importance of indexes in modified approach in comparison to unmodified.

2. Comparing the modified and unmodified indexes’ respective weights reveal an important message. The economic aspect of RE projects is important; however, those who have higher experience and knowledge are aware of the competitive situation of the energy market in a country like Iran. Iran is one of the largest oils and natural gas producers in the world [74]. Therefore, a competitive consumption market between fossil fuels and RE projects is an important challenge to expand more RE projects [75]. On the other hand, government policies to support RE projects is another important acceleration of investment. Although the Iranian government energy policy still emphasizes developing petroleum and gas jointly-owned fields, supportive policies to attract the public sector to invest in RE projects have been raised recently [28]. Therefore, supportive government policies besides managing the competitive energy market are very influential in private sector decisions.

3. In both modified and unmodified scenarios, the top four (4) indexes include ‘Consumption Market’, ‘Conformity with Supportive Government Policies’, ‘Investment Cost’, and ‘Operation

and Maintenance Cost' in which these four indexes together include more than 65% of indexes importance. The results show managing and analyzing these four indexes alone play important role in the RE decision-making process.

6. Conclusions

The recent increasing demand for the RE project needs more private sector participation to invest. Various technical, social, governmental, and environmental aspects affect RE projects which makes the investment decision-making process in these projects more difficult. Considering multiple investment indexes to select the best RE source from an investor's perspective is essential. Most of the studies in the literature utilize group decision making to detect the importance of investment indexes as well as select the best energy alternative. However, in the aggregation process approach, the level of expertise and background of responders is influential on the model result which is not investigated in the previous studies. How those who have higher knowledge in the RE area think differently from less experienced experts?

The main objective of this study is to consider two different scenarios in which to evaluate how the heterogony or homogeneously of the experts affect the result. A modified AHP approach is suggested to evaluate the RE investment criteria. The practicability of the model is demonstrated by selecting Iran as a case study. The results indicate those who have more background in RE projects are more concerned about the competitive energy market as well as government policy and role. Whereas the economic criteria are still the main challenge from a perspective of experts with less experience. Comparing the weighting score in two modified and unmodified scenarios emphasize the government's role in expanding RE projects and attracting more private investors. Both modified and unmodified models chose wind energy sources as the best current alternative energy in the Iran energy market. This study tries to help investors to make more informed decisions in RE investment projects. Comparing the findings with previous works shows that solar and wind energy sources selected as the best RE alternative in Iran frequently. The role of technology and government policies is also highlighted in the prior efforts repeatedly. Future studies might integrate an expert judgment decision-making approach with data-driven techniques to capitalize on available historical data to compare alternative energy sources from economic, environmental, and social benefits resulting in the selection of the best alternative for private sector investment.

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Conflict of interest

The authors declare no conflict of the interest in this paper.

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Appendix

Detailed of questioner's questions to evaluate the expert competency on the subject:

Academic Knowledge: (AK)

- Last educational level: Bachelor ☐ (1 point) Master ☐ (3 points) PhD ☐ (5 points)
- Do you have a research background in renewable energy?

Yes ☐ (5 points) NO ☐ (0 point)

Experience: (EX)

- Work Experience:

Less than 5 years ☐ (1 point) 5-10 years ☐ (2 point) 10-15 years ☐ (3 point) More than 15 years ☐ (5 points)

- Do you have work experience in renewable energy? Yes ☐ (5 points) NO ☐ (0 point)

Professional Performance: (PP)

- Career positions that you have: (Possible to choose several options, each one 1 point)

Project Manager ☐ Executive engineer ☐ Site Manager ☐ Consultor Engineer ☐
Client team ☐

- How many years have you been working in your last job?

Less than 5 years ☐ (1 point) 5-10 years ☐ (2 point) 10-15 years ☐ (3 point) More than 15 years ☐ (5 points)

Project Management practice: (PM)

- Do you have work experience in project management process?

Yes ☐ (5 points) NO ☐ (0 point)

- Do you have a research background in project management process?

Yes ☐ (5 points) NO ☐ (0 point)