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Article

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Evaluation, Hierarchy and Selection of the best Source of Energy by using AHP, as a Proposed Solution to an Energy and Socio-economic Problem, in the case of Colombia's Pacific Zone

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ABSTRACT

This research presents the process and the results to weigh and classify a set of criteria and subcriteria to be considered in Renewable Energy Planning projects for a particular area of Colombia. The implementation of electrification programs in the study area faces various obstacles, among them the inadequate selection of criteria and sub-criteria for assessing the relevance and credibility of the implemented projects, which is very important today, causing huge losses from many points of view. It is proposed to implement a multicriteria methodology (MMCM) that prioritizes criteria and subcriteria, the selected methodology is applied to the use of renewable and conventional energy sources in urban, rural, and isolated regions, one of the most used methods in the best selection process and also when making energy decisions. The Hierarchy Analysis Process (AHP) is used, the data is obtained from a survey to a group of experts with a collection and verification period of about 4 months, only to reduce inaccuracies on the developer side. This study explains the results obtained with a new multipurpose support system that helps to prioritize the most appropriate energy decision criteria and subcriteria of energy options to provide sufficient energy to meet local needs and improve living conditions. Based on the literature review, 4 criteria and 16 subcriteria were identified and submitted to review using the AHP methodology (Hierarchical Analysis Process). It can be determined that the most important criterion is the economic, followed by the social, environmental, and technical, and a hierarchy of subcriteria related to each criterion is established, establishing that for the study area the best source of energy is photovoltaic solar by communities.

Keywords: Hierarchical Analytical Process AHP, Renewable Energy, Decision Making, Multi-criteria, Key Performance Indicators
JEL Classifications: C44, C45, C46

1. INTRODUCTION

At present it is important to obtain electrical energy that meets the standard parameters which guarantee us a quality energy product, that is, that does not pollute the environment, that is always available and that its access is not limited (Srinivasan et al., 2020) The immediate connection between accessibility, quality, safety and the continuous availability of electricity, together with the pricing policy is very close, this in turn is directly related to environmental, economic and social aspects (Campos-Guzmán et al., 2019). The energy sector is in a constant stage of development and progress, so it is essential to know that the goals set have promoted to a greater or lesser extent the great advances that are needed to satisfy environmental, economic, social requests, etc. From another point of view, renewable energies have a leading role in our daily lives, since, today, and with all the technological advances and studies carried out, it is possible to discover or have an estimate of our fossil fuel reserves, and all the other ways we have to produce electrical energy (Moreno et al., 2022).

The economy of a country, its industry and evolution complement each other when within them there is a good use of the electrical energy provided within it, promoting and promoting all sectors at once (Perez-Moscote and Tyagunov, 2022). From a socioeconomic point of view, the way in which the population of a region or country lives, the opportunities that the inhabitant has to be employed and develop as an individual makes sense when the energy consumption that is put at their service is of quality, which is reflected in several aspects of their life (Manuel et al., 2022). Taking into account the previous idea, Colombia does not escape from this logic at any time, there are great interests of different aspects for which, the Pacific region wants to increase the supply of electricity, and achieve an energy matrix where the use of renewable energy source is promoted and encouraged and mitigate its economic-social and energy problems (Moreno and Larrahondo, 2021). In renewable energy projects, government policies can influence prices, and in the same way in the aspects discussed above (Guzman and Henao, 2022) The considerations for taking into account and carrying out renewable energy projects is that they must contribute to the society in which they are preparing to enter, and their economic, social, as well as environmental impact must be estimated; therefore, it is not a simple job (Moreno Rocha et al., 2022) The investments and proposals for this type of projects are numerous and many global policies aim to strengthen this branch with different types of incentives such as low interest rates, accelerated depreciation opportunities, certificates that are negotiable, etc. (Barrera et al., 2021) However, the pacific region of the country is characterized by having high richness in biodiversity, but a factor that impacts on this region, in this case poverty and inequality, on the part of government entities has been of great disinterest to contribute with aid to reduce poverty and take great advantage of what this region offers without attacking or impacting the environment; therefore, living conditions and high poverty have a great impact, analyzing living conditions at the national level, the Pacific region is far below, characteristically the Choco area is where the impact of poverty is highest (Villada et al., 2021).

The research developed here wants to provide a solution to choose the alternative that best suits in terms of electricity generation having renewable energy sources as resources and considering hybrid systems, these two ideas together would build the most optimal alternative.

From an energy point of view, the resources in this area of the Colombian Pacific region are scarce due to the different characteristics that occur in its territory, which we have been mentioning above, it is discouraging to find that the electric service is not efficient, and therefore daily its population is supplied from 4 to 6 h on average (Maity et al., 2022). The great scarcity of tools that promote the decisions of potential investors in renewable energies is a pillar in which you want to work, since the investment of companies is not very diversified, it is chosen because the chosen one is the one that generates the greatest profitability and less risk presents, always having in these projects the basic aspects that we have already handled previously, technical, economic, environmental, etc. (Zhu et al., 2022) The main achievement that we want to obtain in this research is the mathematical development of a model that allows the best choice of an alternative when investing in energy sources. For this reason, the AHP (Analytic Hierrarchy Process) method is proposed, through which taking decision criteria a weight is assigned to the importance of each one, and the same analogy is applied to the evaluated alternatives, so that the result is the best possible option(Mendonça and Haddad, 2022) The AHP method, having criteria as important as economic, environmental, technical, social, among others, gives it a differentiating point among many other investigations of the same topic (Karakas and Yildiran, 2019) This research addresses energy planning, the restricted budget that the country may have, as well as the availability of resources in the last decade (Magazine, 2017) As a consequence, this instrument is considered as a guide for private companies and government entities that wish to access electricity generation projects by making one of the renewable energies (Gielen et al., 2019) A similar survey was conducted in Colombia with the support of the Ministry of Mines and Energy to select the best energy alternatives to address connectivity issues in unconnected regions.

In 1999, the Mining-Energy Planning Unit (UPME), with the cooperation of the community and the private sector, contracted the supply of electricity to the national territory ZIN (Gielen et al., 2019) Studies have shown that, in Colombia (OJEDA Camargo et al., 2017) projects involving NIZ are analyzed considering technical feasibility and economic viability, but not other evaluation criteria. However, in addition to technical and economic feasibility, other criteria are also considered here, such as social and natural criteria. Information on the application of renewable energies is presented. In the second section, the method under study is applied, analyzing the selection criteria and subcriteria. Thirdly, the discussion of the results obtained and the comparison with those of other researchers that is presented, and, finally, the conclusions of the work are provided.

2. MATERIALS AND METHODS

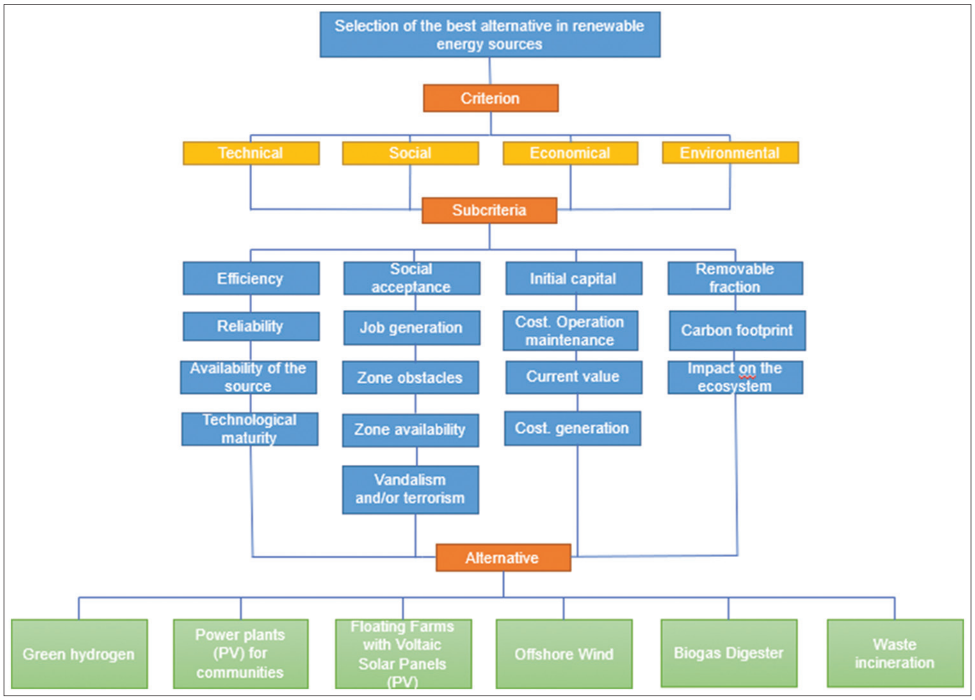
In this study, research is carried out to establish the potential of renewable energies that can be used in the Colombian Pacific region, using the AHP or hierarchical analytical process (Kabir et al., 2022) In this analysis, criteria and sub-criteria are evaluated with the various types of renewable energy, as well as those associated with the environment, social and economic problems, among others, that we find in this area (Zanghelini et al., 2018) For this reason, the research proposes to use the AHP, to prioritize renewable energy sources taking into account that each area represents an important energy potential (Zhu et al., 2022).

2.1. Renewable Energy Alternatives

In the analysis and research of the potential of renewable energies in the Colombian Pacific region, social, environmental, technical and economic are valued, and there are a series of criteria and sub-criteria that are related to them (Carpitella et al., 2018) Alternatives for the use of renewable energies in the region investigated are also taken into consideration Figure 1. teaches the hierarchical structure of decision-making considering the sub-criteria and criteria of the alternatives examined (Thomasi et al., 2022).

To take the best solution requires an analysis of the many variables, criteria, research and other aspects in order to obtain the most

Figure 1: Hierarchy of the AHP model for the study area



viable solution when all points of view are considered, since on different occasions the problems, economic, environmental or social are more complex than what is achieved (Savino et al., 2017). For this reason, the use of the AHP method is suggested, since it provides a resolution of the most complex problems by identifying their causes (John et al., 2014).

2.2. Model Training

The innumerable variables that are present and in a constant transformation of each of the scenarios in which we work give us an idea of how important the mechanism of decision making is because of how complex it can be. Taking into account the above, the multi-criteria processes originated to face this type of (Ferretti and Montibeller, 2016) The structure of the AHP method provides a clear view of the problem and also of the creation of goals, for the identification of alternatives that solve the problem (Alptekin, 2012).

In the previous figure the proposed alternatives are defined, where we find Green Hydrogen, waste incineration, digester or biogas, offshore wind, floating pv farms and finally, pv by communities; Likewise, the criteria for research are observed, which are, technical, social, economic, and environmental criteria.

2.2.1. Step 1: Modeling

In this phase, the hierarchical sequence of problems is implemented and the goals, criteria and alternatives to be implemented are defined according to the criteria of the experts. Next, the alternatives through which the criteria to be evaluated are established are identified; these criteria should take into account the problem and should identify attributes that help make good decisions (Jamal et al., 2020) These criteria must be measured at the level, which is the fundamental objective that we must achieve to solve the problem, and at the second level, the criteria will be positioned according to a descending hierarchy of one or more variables for each criterion. The third and final layer will be alternatives in decision-making (Houlden, 1962).

2.2.2. Paso 2: Reviews

Having understood the alternatives and defined the criteria, we proceed to classify and weigh each criterion when selecting the alternatives. The intention of this process is to measure the importance that decision makers assign to each criterion or alternative i, compared to each criterion or alternative j. A base scale of 1 to 9 was used to assess the relative preference of the items, Table 1 (Robles-Algarín et al., 2018).

In this way, we proceed to construct the matrix of paired comparisons, where a square matrix Anxn = [aij] is obtained, with $1 \leq i, j \leq n$.

For matrix construction, the following axioms must be considered:

Axiom of reciprocity: If A is a matrix of paired comparisons, then it is true that if aij = x then aji = 1/x with $1/9 \leq x \leq 9$.

For the reciprocity property, only n (n-1)/2 comparisons are made:

Axiom of homogeneity: The elements that are compared with each other will be of the same order of magnitude and hierarchy.

Axiom of independence: When the decision maker makes the comparisons, it is assumed that the criteria do not depend on the different alternatives.

Fulfilling the above axioms, it is possible to determine the desired comparison matrix, Table 2.

Table 1: Implementation of the Saaty scale by degree of importance (Saaty, 1980)

Value	Definition
1	Equal importance
3	Moderate importance
5	Great importance
7	Very great importance
9	Extreme importance
2, 4, 6 and 8	Intermediate values

Table 2: Example of a comparison matrix

	A1	A2	A3
A1	1	a_{12}	a_{13}
A2	a_{21}	1	a_{23}
A3	a_{31}	a_{32}	1

2.2.3. Stage 3. Prioritization and synthesis

After comparing the paired matrices, we proceed to calculate since this is a priority part to perform. This underscores the importance that decision makers attach to each element.

The priority is represented as a vector or vectors, assuming that it is a matrix A (nxn), as obtained when making pair comparisons, we call eigenvalues or eigenvectors of A (λ1, λ2,....,λn) to the solution of the equation: det (A- λI) = 0. The principal eigenvalue (λmax) of the matrix is the maximum value of the eigenvalue obtained by performing the above formula (Moustakas et al., 2020).

The principal eigenvalue of {A}, and {a} is the associated eigenvector. The eigenvectors associated with the value of the probabilities are the weighting vectors to be achieved (Zhou, 2012).

So the eigenvector achieved is that of the matrix of criteria, which we call Vc, which represents the relative importance of each criterion selected in the joint evaluation of the alternatives we work (Kim et al., 2019) When the eigenvector obtained is the eigenvector of the surrogate matrix for a given criterion, we call it Vai (column vector), which represents the relative importance of each surrogate matrix for criterion i where as many eigenvectors as standard are obtained. Something that must be taken into account is the final decision is the consistency of the decision maker's decision when completing the coincident matrix (Yang et al., 2022).

In this way, the decision that the policyholder makes is a personal judgment, which leads to an inconsistency that is evaluated to determine if the limits are below the corresponding.

2.2.4. Stage 4. Consistency analysis

This analysis takes into consideration the subjectivity of manufacturing decisions. When performing a process of comparing matrices by pairs, subjectivity is as real and objective as possible because the different elements of a matrix are compared in turn with another matrix (Moghadam and Lombardi, 2019).

On the other hand, there is a procedure to calculate it. If acceptable, the decision-making process can continue, but if not, a new analysis is required, as it can review judgments about peer comparisons. Calculate the consistency ratio using Equation 1 (Strantzali and Aravossis, 2016)

the normalized matrix A:

$$Anormalized\left[\frac{a_y}{\sum_{k-1}^{n} a_{kj}}\right] \tag{1}$$

The sum of rows is obtained from Equation 2:

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}}+\frac{a_{12}}{\sum_{n-1}^{n} a_{n2}}+\ldots\ldots+\frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}}=b_1$$

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}}+\frac{a_{12}}{\sum_{n-1}^{n} a_{n2}}+\ldots\ldots+\frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}}=b_2 \tag{2}$$

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}}+\frac{a_{12}}{\sum_{n-1}^{n} a_{n2}}+\ldots+\frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}}=b_n$$

The priority vector B that is formed is given by Equation 3:

$$\left[\frac{b_1}{n},\frac{b_2}{n},\ldots\ldots\ldots\frac{b_n}{n},\right]^T \tag{3}$$

The product of the original matrix A and the priority vector B forms a column matrix C, Equation 4:

$$A*B=C=\left[c_1,c_2\ldots\ldots\ldots\ldots c_n\right]^T \tag{4}$$

Consequently, the quotient between the matrix column C and the priority vector B is calculated, obtaining another column vector D, Equation 5:

$$\frac{C}{B}=D \tag{5}$$

Adding and averaging its elements, the value of the consistency index (CI) is obtained, Equation 6:

$$CI=\frac{\lambda_{max-n}}{n-1} \tag{6}$$

Subsequently, the CI obtained is compared with the random CI in Table 3.

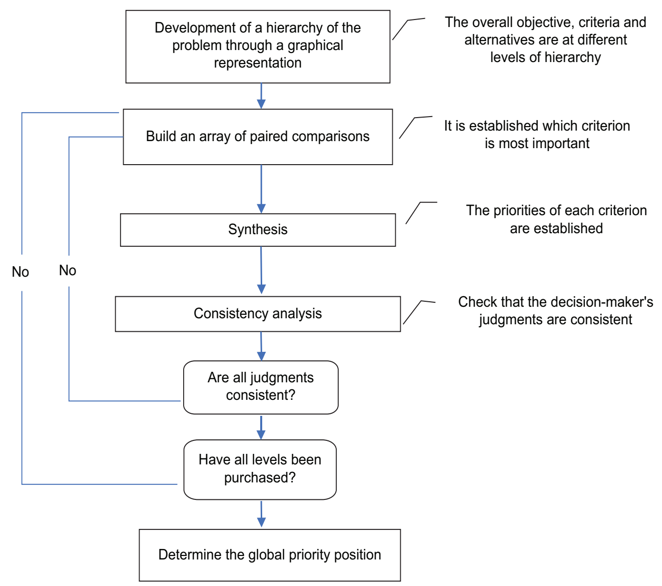
The random consistency (CI) value as a function of the size of the matrix represents the CI value that would have been obtained if the numerical judgments of the scale had been entered into the comparison matrix completely randomly (Coronel and Chasijuan Moreno, 2018).

Therefore, the IC is divided by random consistency, thus obtaining the Inconsistency Relationship (IR), Equation 7:

$$IR = \frac{CI}{Random\,consistency} \quad (7)$$

Finally, we consider a consistent matrix when the stipulated values for the size of each matrix are not exceeded, Table 4. If a matrix exceeds the consistency ratio, the valuations made are verified and changed.

Finally, the correct use or implementation of an AHP model is summarized through logical steps:



2.3. Criteria and Sub-criteria Approach

In the selection of criteria and sub-criteria, a set of qualitative criteria is established, which are conceived as a means of comparison between different alternatives. These parameters influence the multi-criteria decision about which technology to use. The criteria considered in the analysis were based on research on different articles and/or publications from different databases. Table 5 shows the classification of sub-criteria according to social (C1), economic (C2), environmental (C3) and technological (C4) criteria.

Once the final list of criteria is obtained, the interrelationships between the elements for peer comparison are determined. The theoretical definitions of the elements were carefully examined and the literature revised to establish precise interrelationships. The initial relationship was determined based on information obtained from the literature.

On the other hand, the participation of experts in the field of energy also plays a very important role.

In our research, we assembled a team of 15 people, given the multidisciplinary nature of energy investment (teachers, entrepreneurs, professionals in the energy sector, among others); where at least the experts have 2 years of experience and understand the issue of investment in renewable energies.

The experts were asked to review the correlations obtained from the literature and proceed to complete the correlation matrix. The set of scales suggested by (Saaty, 1980) uses a set of scales for comparison matrices, with numbers from 1 to 9, used to indicate the relative importance of the elements. In the next step, the relative importance index of the clusters is determined and the elements are identified. (Saaty, 1980) suggested a set of scales for the comparison of matrices by pairs.

In such a way that the objective of this mythology is to study the criteria, subcriteria and alternatives of a hierarchical Maya to have as results the sentences issued by each of the experts, in such a way in the method, the comparison is made in pairs where an evaluation issued by experts is generated, so that this stage is obtained a successful result will depend on the knowledge and experience of the entities in charge of the taking of decisions.

3. RESULTS

According to the response of the experts consulted for the development of this research and the databases consulted, the following results were obtained; The graph above shows the percentage evolution of households with electricity in the Pacific region, where it is seen as year after year there is greater coverage in the electricity service in the region studied, however, this region is characterized by being ambivalent, that is, despite having many resources to effectively cope with energy demands, we find ourselves with a disturbing reality, where of the 24 h that the service should be provided, only between 15% and 20% are offered, in other words, between 4 and 6 on an average day. That indicates that although households have the service, it is not efficient on a day-to-day basis (Figure 2).

The comparison of the different alternatives with respect to the criterion of the lower level of the hierarchical structure, as the comparison of the different criteria of the same hierarchical level give rise to a square matrix called decision matrix Figure 3. This matrix satisfies the properties of reciprocity (if aij=x, then aji=1/x), homogeneity (if i and j are equally important, aij=aji=1, and, in addition, aii=1 for all i), and consistency (the matrix must not contain contradictions in the valuation made). Consistency is obtained by the Consistency Index (CI) where λmax is the maximum eigenvalue and n is the dimension of the decision matrix.

In the present study, six renewable energies were analyzed, (Solar Photovoltaic (A1), Wind (A2), Biogas Digester(A3), Landfill Biogas (A4), Waste Incineration (A5) and Solar by Solar Collectors

Table 3: Comparison between the obtained CI and the random CI

Array size (n)	1	2	3	4	5	6	7	8	9	10
Random consistency	0.0	0.0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

CI: Consistency index

(A6)), these alternatives were explained in Chapter 2.3 and 2.4 that can supply the energy supply in a non-interconnected urban area, located in the study area.

As for the correct choice of these six energies, it is necessary to carry out an analysis covering all problems, that is, criteria and sub-criteria, with the help of the application of the decision matrix, to generate concrete solutions. For MCDM they are very useful to carry out complex decision-making and energy planning processes, likewise 4 criteria and 16 sub-criteria distributed in each criterion are selected as their sub-criteria based on the research of different articles surveyed in different databases and/or publications, obtain the following standards and sub-standards (explained in detail in Chapter 3.5):

Criteria: Social (C1), Economic (C2), Environmental (C3) and Technical (C4).

Table 4: Limits of coherence (Saaty, 1980)

Matrix size (n)	Consistency ratio
3	5%
4	9%
5 or more than 5	10%

Table 5: Classification of sub-criteria according to criteria

Matrix size (n)	Consistency ratio
Social (C1)	Social acceptance (C 1.1)
	Job creation (C 1.2)
	Obstacles in zones (C 1.3)
	Zone availability (C 1.4)
	Vandalism and/or terrorism (C 1.5)
Economical (C2)	Starting capital (C 2.1)
	Cost of operation and maintenance (C 2.2)
	Net value (C 2.3)
	Cost of electricity generation (C 2.4)
Environmental (C3)	Renewable faction (C 3.1)
	Carbon footprint (C 3.2)
	Impact on the ecosystem (C 3.3)
Technical (C4)	Efficiency (C 4.1)
	Reliability (C 4.2)
	Source availability (C 4.3)
	Technological maturity (C 4.4)

Sub-criteria: Social Acceptance (C1.1), Job Creation (C1.2), Regional Barrier (C1.3), Regional Availability (C1.4) and Vandalism and/or Terrorism (C1.5), Initial Capital (C2.1), Operation and Maintenance Costs (C2.2), Net Present Value (C2.3), Generation Costs (C2.4), Renewable Portion (C3.1), Carbon Footprint (C3.2), Impact on the Ecosystem (C3.3), Efficiency (C4.1), Reliability (C4.2), Resource Availability (C4.3) and Technological Maturity (C4.4).

In the previous Figure 4, you can see the weight and sequence of sub-criteria assigned to the technical standard, and it can be seen that, in the technical standard, the efficiency of the technology used is of greater importance, followed by reliability, the level of maturity Technology and, ultimately, availability of resources, demonstrating the concern that exists in the market for more and more processes to be more efficient, this is because this is evidenced in energy and economic savings.

Figure 5 sample that in the environmental criterion its subcriteria is prioritized so that the renewable part has greater weight, followed by the impact on the ecosystem and finally the carbon footprint, managing to show the commitment that exists by the Colombian government in complying with the international pacts in the conservation of the environment and the mitigation in CO_2 emissions.

Finally, Figure 6 above is presented, which gives the weighting and hierarchization of the subcriteria attributed to the social norm. For this criterion, the sub-criteria of job creation are the most important, followed by the sub-criteria of availability of the region, social acceptability, vandalism and/or terrorism and, finally, obstacles in the region, this classification is of great importance because the study area is characterized by a high impact on poverty, caused by the absence of job opportunities, then through Figure 6 a call is made that all the projects that wish to be generated in that area, must ensure the generation of work in the inhabitants.

For this research, the relationship and sequence of criteria between them also gave observational results in which the economic criterion in 31% turned out to be the most important when implementing renewable energy facilities, followed by the social

Figure 2: Percentages of households with electrical energy

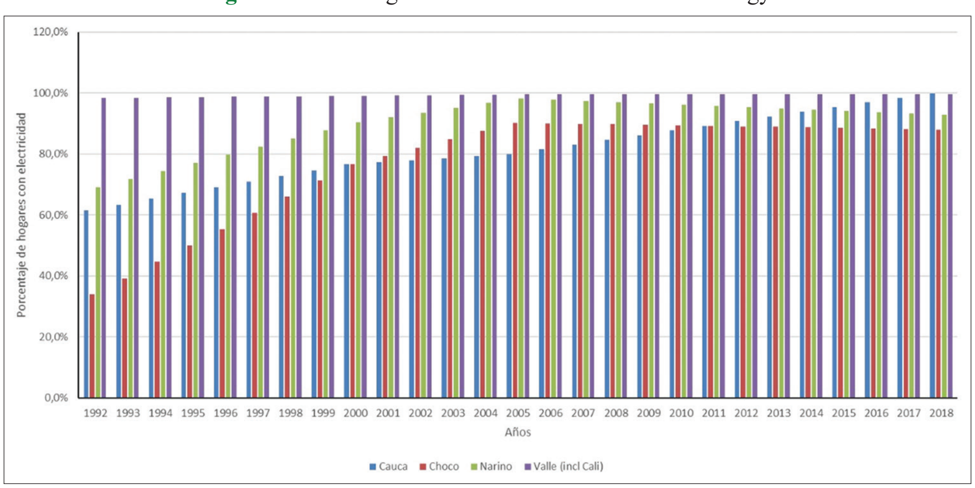


Figure 3: Decision making matrix

	C1 (28%)					C2 (31%)				C3 (25%)			C4 (16%)			
	C1.1	C1.2	C1.3	C1.4	C1.5	C2.1	C2.2	C2.3	C2.4	C3.1	C3.2	C3.3	C4.1	C4.2	C4.3	C4.4
Weight local	0.0012	0.0028	0.0014	0.00172473	0.0029	0.0031	0.0029	0.0018	0.0022	0.004	0.0015	0.0045	0.0042	0.0035	0.0009	0.0015
Weight global	0.00018	0.00042	0.00021	0.00025871	0.000435	0.001178	0.001102	0.000684	0.000836	0.00136	0.00051	0.00153	0.000546	0.000455	0.000117	0.000195
A1	0.217901	0.217901	0.111732	0.204183	0.281280	0.204183	0.162018	0.117946	0.236221	0.167340	0.078737	0.236221	0.090000	0.303289	0.239437	0.316946
A2	0.163089	0.138583	0.109493	0.117946	0.109222	0.135835	0.123521	0.239437	0.153506	0.051280	0.316946	0.114550	0.154956	0.192081	0.179352	0.172477
A3	0.088452	0.180144	0.082222	0.135835	0.138583	0.239437	0.111732	0.183516	0.117946	0.267340	0.012797	0.073671	0.196992	0.221458	0.119312	0.114550
A4	0.206311	0.239437	0.236221	0.183516	0.171672	0.183516	0.152519	0.138583	0.245311	0.154381	0.239437	0.179352	0.281280	0.104933	0.110337	0.110337
A5	0.206311	0.130000	0.042801	0.077634	0.115128	0.033466	0.236221	0.162010	0.148583	0.078737	0.111979	0.082222	0.179352	0.082477	0.198248	0.114550
A6	0.118000	0.090000	0.420000	0.279960	0.179440	0.205743	0.218690	0.153521	0.103115	0.281280	0.239437	0.316946	0.095211	0.092323	0.157788	0.171672

criterion in 28%, followed by environmental standards or criteria with 25% and in fourth place the technical standards with 16% of all options, see Figure 7.

Weights and sequences were also taken from all sub-criteria. Note that when the criteria are specified, all the results obtained are added, they should not fall. When comparing economic sub-criteria with social sub-criteria, only sub-criteria are compared. to sub-criteria of the same criterion.

In this sense, we have evaluated from the beginning the weight, and the impact of the sub-criteria on the ecosystem in the environmental standard, by 45%, which shows us that the change or change in the environment, is cause or effect. of man. activity and intervention. This impact on the ecosystem can be positive or negative, and the negative one represents a disturbance in the ecological balance, causing serious damage to the environment, as well as to the health of people and other living organisms. Secondly, we have the efficiency sub-criterion, in the technical standard, with a weight of 42%, which is defined as the relationship between useful energy and inverted energy. Qualitatively, in this case the efficiency will be higher, since a greater amount of energy is available. Thirdly, in terms of weighting, we find the renewable fraction sub-criterion, at 40%, which indicates the amount of energy, equipment or product that can be reused once it has been used in an activity, another activity or any device, product or activity, comes from the use of a renewable source see Figure 8.

Likewise, in this research the heterogeneous behavior of the different alternatives was evidenced when they are evaluated by established criteria, some of them presented a greater degree of importance when they were evaluated against some criteria, an example of this situation is what happened with the economic criterion which presented greater importance in the technology of incineration of waste and less degree of importance according to the group of experts consulted when the Green hydrogen technology, this same behavior was replicated for the other criteria, thus demonstrating that each energy alternative has its degree of importance when it is evaluated against a specific criterion, allowing to lay a basis for study for future research see Figure 9.

After having carried out the respective analysis, and because of this research, it is established that the best alternative is the energy from the Voltaic Plants by the communities, with 20.20%, being the renewable energy that best fits the requirement of the proposed problem, according to the opinion of the experts and the application of the AHP methodology.

Considering the judgments of the experts, the best renewable energy alternative for the study area is the Voltaic Plants (PV). The selection of this renewable energy is in the availability of resource found in the area. Thistype of facility is part of an energy transition that is very difficult to secure today. In principle, the installation of solar panels aims to benefit the community and at the same time the neighbor.

On the one hand, the energy obtained can be destined to common elements of the house, so that the common bill is lower; and,

Figure 4: Hierarchy of technical sub-criteria

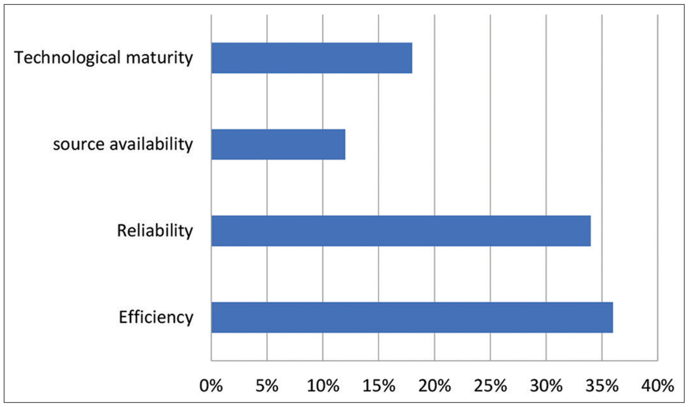


Figure 5: Hierarchy of environmental sub-criteria

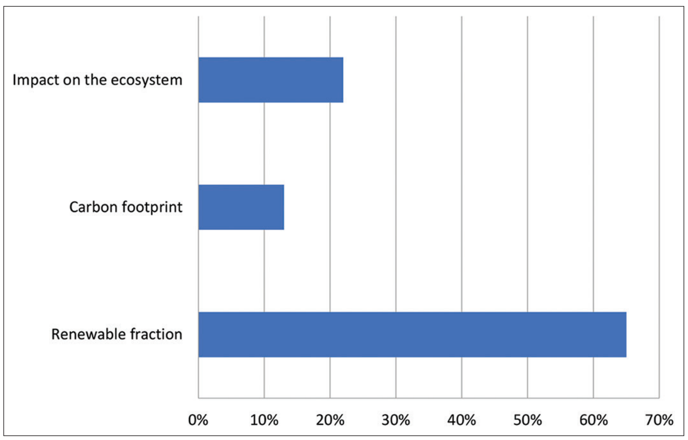
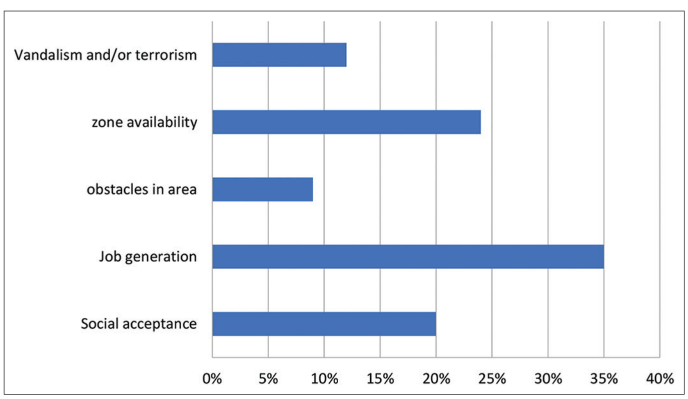
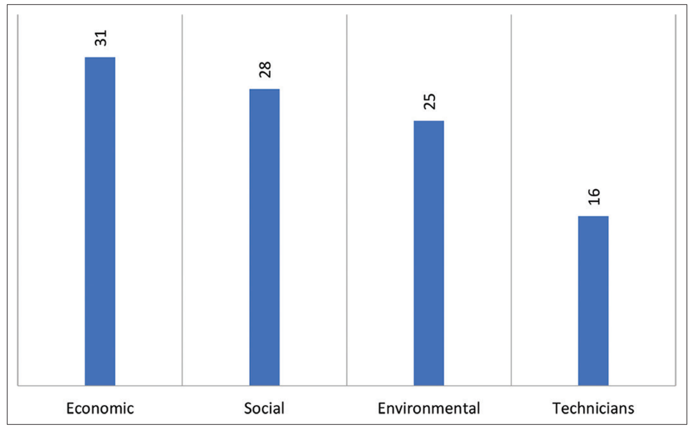


Figure 6: Hierarchy of social sub-criteria



on the other hand, it will benefit those who have invested in the installation and will see the variable cost of light reduced. It is essential that for there to be a greater profitability of this energy, it is necessary to try to sell the surplus electricity, as long as the modality of self-consumption is with surpluses. Since March 2020 it is possible to request to be paid for the sunlight that you do not use, in addition, this type of energy does not generate any type of noise pollution, so it is not harmful to the communities of neighboring neighbors. Among the benefits and advantages of solar energy installations in neighboring communities; The levels of pollution caused by the production of electrical energy through conventional systems are greatly reduced and the free and inexhaustible natural resources offered by nature are exploited.

Figure 7: Percentages of % criteria



Secondly, the best alternative presented is Floating Farms with voltaic solar panels (PV), with 17.30%. It corresponds to a solar farm or field where there is an enclosure or space in which small photovoltaic installations different owners share infrastructures and services. The solar farm is a solar power plant and refers to a large, more industrial installation composed of several solar plants that require a centralized control room and high-voltage transformers. It refers to individual installations of small producers with the intention of producing small-scale energy to sell to the electricity grid. Solar orchard has its origin in the agricultural character because they are made on top of orchards, fields, pastures or vineyards and because metaphorically the sun is cultivated to produce energy as another crop of the earth.

Thirdly, the alternative presented is the use of Digester or Biogas, with 16.6%. A biogas reactor or anaerobic digester is an anaerobic treatment technology that produces a digested mixture (digestate or biol), which can be used as fertilizer and biogas, which can be used as an energy source. Biogas is a gas that is generated in natural environments or in specific devices, by the biodegradation reactions of organic matter, through the action of microorganisms (methanogenic bacteria, etc.), and other factors, in the absence of oxygen (that is, in an anaerobic environment), which in a given process can produce electrical energy.

The production of biogas by anaerobic decomposition is a useful way to treat biodegradable waste, since it produces a valuable fuel, in addition to generating an effluent that can be applied as a soil conditioner or generic fertilizer. The result is a mixture consisting of methane in a proportion ranging from 50% to 70% by volume, and carbon dioxide smaller proportions of other gases such as hydrogen, nitrogen, oxygen and hydrogen sulfide/hydrogen sulfide. Biogas has an average calorific value between 18.8 and 23.4 Mega-Julios per cubic meter (MJ/m^3). This gas, properly purified, can be used to produce electrical energy through turbines or gas generating plants, and to produce heat in furnaces, stoves, dryers, boilers, heating or other properly adapted systems.

Fourth, we have the option of Offshore Wind Energy, with 16.10%. Wind farms are not only built on land. Also at sea, away from the coasts: they are called offshore or offshore wind farms. The planet's resources are depleted and it is urgent to seek solutions that promote their care and sustainability. There is a source that

Figure 8: Percentage weighting of sub-criteria

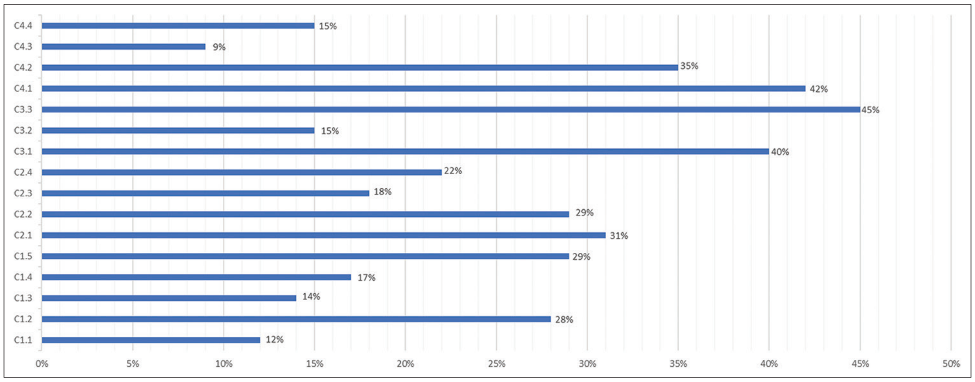
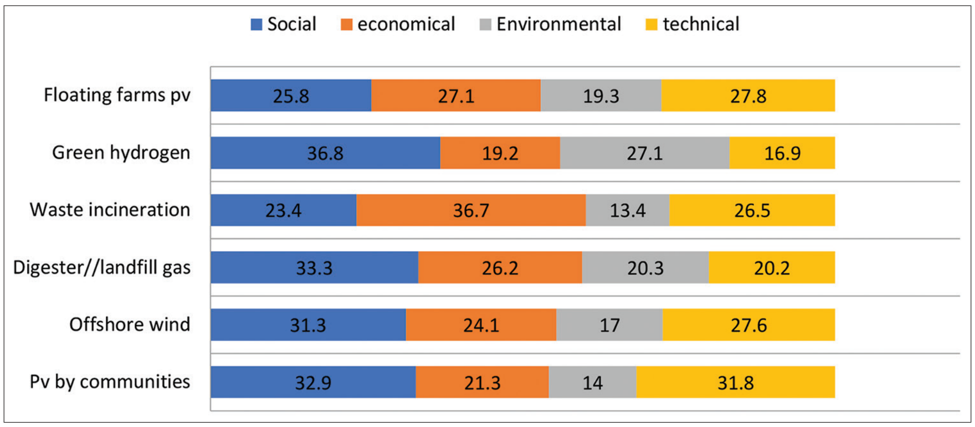


Figure 9: Weighting of each energy source versus the evaluated criteria



has the necessary properties to offer a viable solution to energy challenges: offshore wind energy. In recent years, offshore wind power has gone from being a secondary source to being a global resource through an increasing capacity of isolated turbines from 30 kW to 10 MW in just 30 years and an overall project-level capacity of 5 MW to more than 600 MW. Simply put, it has become the mainstay of the renewable energy industry.

Fifth, we have the alternative of energy through green hydrogen, with 15.07%. This method uses electric current to separate hydrogen from oxygen in water, so if that electricity is obtained from renewable sources, we will produce energy without emitting carbon dioxide into the atmosphere. To obtain electricity from hydrogen, the reverse reaction is carried out precisely than for obtaining hydrogen. In this case it is reacted with oxygen, obtaining electricity and water. The device responsible for performing this reaction is called a fuel cell. Our way of life needs more and more watts to function. The latest estimates from the International Energy Agency (IEA), published at the end of 2019, forecast an increase in global energy demand of between 25 and 30% until 2040, which in an economy dependent on coal and oil would mean more CO_2 and the aggravation of climate change. However, the decarbonization of the planet proposes a different world by 2050: More accessible, efficient and sustainable, and driven by clean energies such as green hydrogen.

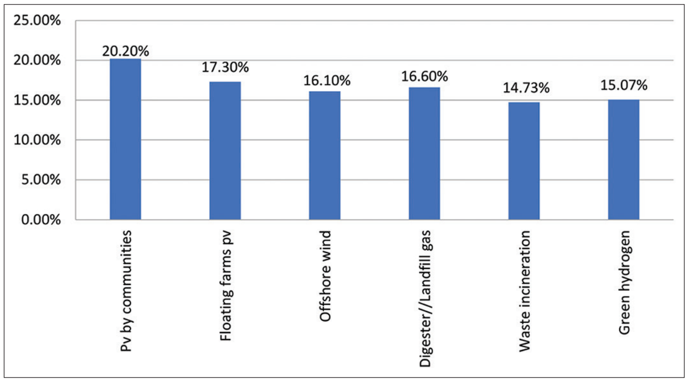
In last place in the alternatives, we have electricity from the incineration of waste, with 14.73%. The heat from the waste incineration is used to drive the steam boiler and drive the steam turbine to generate the energy. By compacting the waste due to incineration, it is effectively used for the landfill. Incinerable waste in a pit is incinerated after being sent through the air to the mechanical loader furnace. The high-temperature combustion gas of approx. 800°C is recovered by the steam boiler. The steam generated by the boiler is sent to the steam turbine and used to generate the power. After the heat from the exhaust gas has been recovered, it is treated in the treatment facility to a value that is below the environmental standard and discharged into the atmosphere. The incinerated waste is extracted as flying ash and after compaction up to 1/10 of the volume of the waste, it is disposed of in landfills see Figure 10.

4. CONCLUSIONS AND RECOMMENDATIONS

The use of multi-criteria decision-making methods, with the aim of finding the right choice among several alternatives, becomes a powerful tool in times of large projects and not only at renewable energy levels, but also in general. For any small or large company, public or private, it is more than ever subject to decision-making in various areas: infrastructure, economy, human resources, etc. The specific use of MCDM occurs due to the complexity that a set of alternatives presents when evaluated against a set of criteria and these in turn are additional criteria.

The application areas of MCDM are many, for this research they focused on the field of renewable energies. Gradually over time,

Figure 10: Renewable energy alternatives %



the importance of renewables has increased due to the benefits when applied for the benefit of a large population or industry. The right choice of renewable energies depends on many factors that prevent or allow their correct development, because the goal is to obtain significant benefits, not losses. The wrong decision when choosing renewable energies using the resources available in the field of application will be a huge waste of time and money.

Therefore, the methodology described in this article will help in making decisions that can focus on public policies that tend to take advantage of the energy resources available in research and subsequent application. The method chosen in this study is AHP with application of fuzzy logic, also known as AHP. AHP provides a hierarchical analysis process, while experts in fuzzy logic models are ambiguous or unclear about the criteria and sub-criteria being evaluated, meaning that the AHP eliminates or reduces subjectivity, the concerns that each expert may raise when giving you an answer.

It is important to note that AHP theory consists of a well-organized set of three basic elements. Systems based on fuzzy numbers are an excellent tool for modeling languages and numbers. This leads to the large and extensive calculations needed to implement the above method, which creates great difficulties, if it were not for programs that perform many arithmetic operations.

Due to the whole process that was carried out in this study, where PV by communities occupies a first place with 20.20%, followed by floating PV farms with 17.30%, as a third option you could opt for Offshore Wind with 16.10%, as the fourth alternative Digester or biogas 16.60%, continuing waste incineration with 14.73% and finally alternative, green hydrogen with 15.07%. It is very important that the switch between renewable energy and another percentage, which demonstrates the complexity of the selection with a simple analysis. The results obtained in this survey were used to confirm or unify, the studies carried out by the Colombian government to invest in improving the quality of life of people in the region, in which they were presented. The same results, even if they are definitely using very good analysis techniques. Overall, this ensures that the method has achieved its mission and provides the honest results needed to make the right decision. Although AHP was used for this study, this does not mean that other MCDMs are ineffective or less important, as shown in the theoretical support for these arguments, there are other reasons to use the AHP method. From a general point of view, the route is not restricted, that is, the same search can be performed together with another MCDM. It is expected that this research will be used as a basis for future research and will also be used as a tool to achieve the mitigation of the energy problems that the study area has always suffered, achieving with this possible mitigation an improvement in the quality of road of its inhabitants.

There is always room for future recommendations in any study that improve the process and therefore the results obtained. Knowing that surveys are conducted with a team of experts, it is recommended to use a licensed online survey form, which is ideal for storing data and can be accessed at any time. In this way, when calculating the method, the data will be easier to use, and there is no drawback in taking priority vectors.

The second recommendation is that, since the AHP method is a multicriteria or subcriteria decision support method, in this way the subjectivity of expert judgments can be reduced when fuzzy logic is applied. In addition, the application of fuzzy logic can be extended to other MCDM devices, in addition to this study, better results can be obtained. Another recommendation is that due to the long time spent developing the entire mathematical procedure for the applied AHP method, the use of MatLab is presented as a suggestion, since it can work with any type of matrix and will run immediately, so it can be programmed adjusted as needed. In addition, MatLab is a program that has a native engine in SimuLink called "Fuzzy Logic Controller," which can be quite useful.

The final recommendation for future research is to use this hierarchical procedure with fuzzy logic and then compare the results obtained, but currently it is focused on solving electric power in a community that is not connected to each other or to the electric power service.

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