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Use of MCDM Techniques for Renewable Energy Policy & Decision-Making Problems: A Systematic Review

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Abstract: Energy consumption has become an increasingly alarming issue and is widely discussed among policy makers today concerned about the allocation of the limited resources that are left. This has prompted researchers to search for new, more experimental, inexhaustible sources of energy that can be sustained for the foreseeable future. At this point, many agree that renewable energy is the way forward. The crux of the issue however lies in what source should be used, which technology should be adopted and what factors associated with generation, transmission and distribution should be considered in order to create the most robust energy policy applicable on a large scale but with enough room to be reinterpreted and adapted to a particular country or business. Multi-criteria decision making (MCDM) techniques are effective tools to help researchers solve complex decision-making problems taking multiple conditions and criteria into account to provide the best alternative available. Analysing studies as per authors, publication year, document type, statistics and graphical representations, country of origin and source of publication can be advantageous for researchers in the decision-making field, allowing them to create a timeline tracing the application of MCDM techniques in the field while also building and adding to this area of research. This study has reviewed 202 research papers to analyse existing research, identify research gaps and propose new future research opportunities in the area of energy policy formulation for solving decision-making problems through the application of MCDM techniques.

Keywords: Renewable energy; Multi-criteria decision making (MCDM); Analytic Hierarchy Process (AHP); Sustainable energy; Analytic Network Process (ANP)

1. Introduction

Over the past several years, there has been a significant increase in the demand for renewable energy and the motivation to switch to it for a variety of purposes. However, precisely what is renewable energy. Renewable energy comes from natural sources that replenish themselves more quickly than they deplete are devoured. For instance, wind and sunlight are two such sources that are replenished. There are many different types of renewable energy available to us. making multiple decisions. The criterion (MCDM) theory is a method for choosing the best choice from numerous options to achieve the desired result .When it comes to distribution of resources, formulation and adoption of the optimal decision-making policy, process, procedure or technique becomes of paramount importance. This has become even more crucial in the last twenty years with the dearth of resources felt even more acutely. One resource, energy has always been of chief importance from an economic, socio-political, technological and environmental standpoint.

The world's energy map has changed dramatically during the last 40 years, not only in the increase in the demand for all of the energy sources but also in the contributions of each source at a global level (Arce et al., 2015). Traditional single criteria decision-making approaches cannot handle the complexity of current systems and this problem (Abu Taha & Daim, 2013a). Providing cheap, good quality, on time and safely of energy is one of the priority issues of country management (Şengül et al., 2015). Countries whose economies are heavily linked to fossil-fuel production will need to diversify their energy production e.g., by using more renewable energy (Alizadeh et al., 2020). These countries are characterized by face increasing energy consumption, high-energy intensity, extensive emissions, economic and political challenges (Alizadeh et al., 2020). Renewable energy is the inevitable choice for sustainable economic growth, for the harmonious coexistence of human and environment as well as for the sustainable development (Ertay et al., 2013) . More and more researchers are interested in renewable energy sources since they cause less greenhouse gas emission and known as clean and environment-friendly energy alternatives (İ. Kaya et al., 2019). Marques et al. (2010) show that the effect of Gross Domestic Product (GDP) on the development of renewables is not uniform, but depends on the level of utilization of renewable sources (Marques & Fuinhas, 2012). In this regard, reviewing energy policy to determine the best techniques to adopt to ensure ideal planning, generation, supply and distribution of energy has become the need of the hour. For most nations, energy is currency and those countries that have abundant energy sources will reign supreme as leaders of the world economy. This has prompted countries to shift their focus to sustainable renewable sources of energy. A generation defined by conscious consumers with a conscience, who are entering into the markets, workforce and voting booth we felt the need to write a literature review detailing and evaluating alternate sustainable energies as well as various Multi Criteria Decision-Making (MCDM) models that can be used to implement the best possible solution.

In their analysis of sustainability challenges, authors contend that inter-disciplinary approaches to decision-making are necessary in order to achieve a long-term balance between each particular system. Energy trend forecasting and backcasting, scenarios and system analysis have matured into powerful modeling tools for providing advice on optimizing our future energy solutions (Weijermars et al., 2012). The activities of energy planning and decision-making now include considerations for the environment due to the expanding environmental concerns and the growing negative environmental effects of the use of energy resources. Since the 1980s, planning energy system activities has grown in significance as a tool for decision-making and as

a means of attempting to lower the costs of rising energy resources and the issues associated with resource scarcity.(Siksnelyte et al., 2018)

Decision making theories and applications offer different modelling techniques, provide appropriate approaches for modelling decision aiding, help in development of alternatives as they take into account the complexity of the process (Zavadskas & Turskis, 2011). Multiple criteria decision making (MCDM) is a branch of operational research dealing with finding optimal results in complex scenarios including various indicators, conflicting objectives and criteria (Kumar et al., 2017a). This tool is becoming popular in the field of energy planning due to the flexibility it provides to the decision makers to take decisions while considering all the criteria and objectives simultaneously (Kumar et al., 2017a). MCDM illuminates and quantifies the stakeholders' and decision makers' considerations regarding (mostly) different non-financial elements in order to make a comparison between different courses of action (Mardani et al., 2017) . Many of the original MCDM methods have also been extended or adapted by the creators of those theories and by researchers on these methods (Saaty & Ergu, 2015). With these variations we have more than a hundred MCDM methods (Saaty & Ergu, 2015) . One common character of these techniques is that the evaluation criteria and available alternatives for selection are defined at the beginning, and then evaluated one by one by DMs to ultimately find a preference ranking of alternatives (Büyüközkan et al., 2018) . The most important advantage of the multiple criteria methods is their capability of addressing the problems that are marked by different conflicting interests (Mardani, Jusoh, Nor, et al., 2015). Using these techniques, actors are capable of solving the problems that it is not possible to solve by the use of common optimisation models (Mardani, Jusoh, Nor, et al., 2015).

Off-grid energy systems largely benefit the society as in remote areas of developing countries, they have the potential to benefit small off-grid communities and are socially acceptable and environmentally friendly. However, some studies Off-grid energy systems are not economical in developing countries compared to grid-connected renewable and conventional energy system This conflict COVID-19 pandemic as some local factors may affect the future planning process. Renewable energy projects are planned to rapidly replace fossil fuels. Energy planning using MCDM has attracted the interest of various decision makers for a really long time. The methods used in this provide solution to complex and time-constraining energy management problems. Thus, with the help of this model we will try to aim at maximization of benefits and minimization of costs and adequate as well as sustainable use of renewable energy.

This study aims to provide a cohesive look at different MCDM techniques that may be used at different stages of renewable energy formulation. This would prove to be beneficial as our study would be able to amass as well as add information for designing a renewable energy policy in its entirety rather than having to refer to multiple articles at different stages of the process. The examples were selected in a way to give an extensive overview of all approaches and techniques applied to environmental, sustainable and renewable energy issues during recent years (Mardani, Jusoh, Zavadskas, et al., 2015a). This paper also evaluates the most important advantages of various approaches and techniques, and the difficulties that they may face (Mardani, Jusoh, Zavadskas, et al., 2015b). Finally, this study argues that MCDM is practical for solving

problems in sustainable and renewable energy issues with multiple resources (Mardani, Jusoh, Zavadskas, et al., 2015b).

2. Literature Review

In many developed and emerging nations, the availability of renewable energy sources is quickly expanding. Wind and solar photovoltaics (PV), two popular renewable energy sources, have shown tremendous growth in recent years. The fundamental tenet of all policies for the development of renewable energy is that they stimulate the market. An integrated renewable energy system consists of various transmission components, energy storage, and renewable energy generating. Even if the life-cycle efficiency of a renewable energy system is less than 100%, it will still be more sustainable than a fossil fuel system. Modern renewable energy technologies are increasingly being used.

We begin by providing a quick summary of the data, which includes energy demands, energy output based on time horizon, and the problem's geographic scope. Actually, fossil fuels are used to meet the majority of the world's energy needs. Renewable energy sources including solar, wind, geothermal, hydro, and biomass make up a much lower portion of the energy generation process. The second step is to determine the energetic flows coming from the different conversion systems associated with renewable energy sources (Wind, solar, small hydro, geothermal, biomass). Each conversion system can be distinguished from the others based on its production capacity, efficiency, and the presence of institutional, economic, environmental, and technical constraints as well as regional and local peculiarities. For RES exploitation at this stage, the use of a multicriteria decision-aid methodology is suggested. One of the most crucial issues is choosing the evaluation criteria. To avoid contradictions when determining value trade-offs between the various issues, the range of all criteria must be expressly indicated. The suggested strategy represents an effort to recognise and address every factor deemed crucial for the choice of RES exploitation. It highlights the components and actions that ought to go into the evaluation process and develops a broad estimate of the timetable for energy production. The conclusion reached is that the solutions that were taken into consideration should be suitable for regional energy planning and integrated renewable energy appraisal projects.

Numerous energy-related issues, such as energy planning, energy policy, and management of energy, have been addressed using multi-criteria decision making (MCDM) techniques. MCDM can help achieve what may seem like conflicting objectives. It can help maximise profits by minimising costs. MCDM methods include WSM, analytic hierarchy process, technique for order of preference by similarity to ideal solution, elimination et choice translating reality, VIKOR. Each method has its advantages and disadvantages as well as application fields. Multiple methods can be used to solve a problem.

This section reviews the application of MCDM techniques in evaluating renewable energy policy areas which entails assessing renewable energy sources, generation, supply, technologies and distribution. The following sub-section will review the application of the MCDM methods mentioned below in detail.

2.1. Applications of MCDM methods

i. Analytic Hierarchy Process (AHP)

ii. Analytic Network Process (ANP)

iii. Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS)

iv. Elimination and Choice Translating Reality (ELECTRE)

v. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

vi. Multi-Attribute Utility Theory (MAUT)

vii. VIKOR Method

viii. Grey Incidence Method (GIM)

ix. Simple Multi-Attribute Rating Technique (SMART)

x. MULTIMOORA Method

xi. COPRAS (Complex Proportional Assessment) Method

xii. Weighted Sum Method (WSM)

xiii. BOCR Analysis

2.1.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process or AHP is an MCDM technique developed by Thomas L Saaty. AHP is extremely popular as it takes into account both quantitative as well as qualitative decision-making criteria. AHP can handle multiple conflicting objectives (economic, environmental, socio-political etc.) while it gives the opportunity to deal with different perspectives of stakeholders. These specifications very much satisfy the nature of decision making for energy systems. On top of all these, some socio-technical criteria are very difficult to be quantified whereas AHP resolves this hurdle by enabling pair-wise comparison of them against each other (Institute of Electrical and Electronics Engineers., 2013). The first step in AHP is defining the problem which in this case would be to choose the best energy policy. This should be followed by structuring the decision hierarchy which starts with a goal and subsequently defining the criteria and sub-criteria against which alternatives will be evaluated. The third step as mentioned by Saaty would be to construct a set of pairwise comparison matrices using Saaty's nine-point scale to convert qualitative decisions into numerical values. At the last stage, weights must be assigned to the respective criterion and the alternative with the highest weight is selected as the best one. Ahmad and Tahar examined renewable energy sources for sustainable electricity generation by taking technical, economic, social and environmental factors into account (Ilbahar et al., 2019). Hydropower, solar, wind, biomass are the renewable energy sources considered in their study (Ilbahar et al., 2019).

This technique breaks down a complex system into a hierarchy of components, which often includes an ultimate goal, evaluation criteria, and alternative options. The final scores of the alternatives are calculated

by weighing several evaluation indexes in accordance with the ultimate objective and the alternatives from the viewpoint of each evaluation index. Then, comparisons are quantified to create a comparison matrix, and the matrix's eigenvector—which denotes the relative weight of different items within a given hierarchy—is generated. It has been demonstrated to be successful in constructing a variety of difficult multi-criteria evaluations, particularly for issues including numerous quantitative and qualitative aspects. (S. K. Lee et al., 2009; Ren et al., 2009)

The AHP approach was created by Saaty in the 1970s as an alternative to the then-current methodologies. To solve issues, a hierarchy process is used (Theodorou et al., 2010).

The decision maker starts a prioritisation process after creating a hierarchy to decide the relative importance of the components at each level of the hierarchy. The components of the normalised eigenvector linked to the biggest eigen value of their comparison matrix represent the relative weights of each level's items in relation to an element in the neighbouring upper level. The priority aim was established at the first level. Four factors—technical, economic, environmental characteristics, and local primary energy resources—are taken into account at the second level. (Bhattacharyya, 2012; Güngör et al., 2009)

The premise that a ration scale preference exists and the numerical interpretation of the semantic scale have both been hotly contested issues with regard to the AHP. (Theodorou et al., 2010)

The AHP is a tool that academics and decision-makers use to calibrate a numerical scale for measuring both qualitative and quantitative performance. It entails breaking down a difficult choice into a hierarchy with the objective at the top, criteria at levels and sublevels, and decision options at the bottom. (Kahraman et al., 2003; Wang et al., 2008)

AHP has been extensively used to evaluate power plants and determine development priorities (Elkarmi & Mustafa, 1993). For instance, Chatzimouratidis and Pilavachi used AHP to analyse how power plants would affect people's quality of life, taking into account factors including CO2, the amount of land needed, the generation of jobs, and societal acceptance. According to their findings, under various criteria, solar PV, oil, coal, hydro, and wind power facilities are the most stable. AHP was used by Amer and Daim to assess four different RE technology alternatives. A total of 20 variables were considered, including technical, economic, social, environmental, and political elements. The investment cost and electric cost are the two most crucial criteria. The findings show that wind and biomass energy are the two most popular options. AHP was used by Ahmad and Tahar for the selection of RES in Malaysia. Twelve sub-criteria were included in their analysis, including twelve technical, economic, social, and environmental factors (such as maturity, effectiveness, public acceptance, job generation, CO2 emission, and land requirement). Efficiency and CO2 rank as the second and fourth most crucial criteria, respectively, according to their findings. They recommended that solar PV, followed by biomass, hydropower, and wind, is the best RES for Malaysia. In order to assess the rankings of various renewable and non-renewable electric energy production methods according to 11 key criteria, Stein developed a thorough multi-criteria model based on actual data (A. H. I. Lee et al., 2009; S. K. Lee et al., 2007). They came to the conclusion that geothermal, hydro, wind, and solar energy all give the best overall advantages (Chatzimouratidis & Pilavachi, 2008). We can also refer to fuzzy AHP methods. (D.-Y. Chang, 1996)

2.1.2 Analytic Network Process (ANP)

Analytic Network Process (ANP) is essentially an extension of the pre-existing Analytic Hierarchy Network (AHP) introduced by Saaty and improves upon AHP by taking into account mutual dependencies. Iskin et al. adopted ANP to examine factors influencing renewable energy pricing by taking social, technical, environmental and economic aspects into consideration (Ilbahar et al., 2019). Atmaca and Basar evaluated natural gas, wind, geothermal, hydroelectric, coal/lignite, and nuclear energy plants using ANP while taking technology and sustainability, economic suitability, life quality, and socio-economic criteria into account (Ilbahar et al., 2019).

Analytic Network Process (ANP): Both the AHP and the ANP methodologies were developed by Saaty. Although AHP is simple to use and put into practise, it cannot handle many situations' complexity due to its unidirectional relationship characteristic (Abu Taha & Daim, 2013a). An empirical example of the application of ANP is provided by Cheng and Li (Abu Taha & Daim, 2013b).

2.1.3 Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS)

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a technique that was initially suggested by Hwang and Yoon. This method determines the best alternative by using distances of the alternatives to positive and negative ideal solutions (İ. Kaya et al., 2018a). As per (Kumar et al., 2017b), TOPSIS can be used for energy planning, energy supply strategies and energy management strategies. In Turkey, a TOPSIS model was implemented in order to make a decision between various energy alternatives and sustainable electricity production technologies (Şengül et al., 2015).

TOPSIS is founded on the assumption that the ideal alternative meets all criteria at the highest level, while the negative ideal meets all criteria at the lowest levels. The fundamental notion is that the optimal option should be chosen if it is geometrically closest to the ideal positive solution and farthest from the ideal negative solution. The approach makes the assumption that each attribute's utility either increases or decreases monotonically.(Wang et al., 2008)

The importance weight of alternative renewable energies can be calculated using the TOPSIS approach. This approach contains three main steps used by Iran for their energy policies:

1. First, defining the criteria for selection (or evaluation). These criteria were chosen after a review of the literature and expert interviews.
2. After creating the hierarchy of evaluation criteria, apply the FAHP method to determine the weights of the criteria. The hazy scale for determining relative weights uses relative relevance. (Kahraman et al.) have proposed this scale.
3. FTOPSIS is used to produce the final ranking results. measuring the relative weights of options using a fuzzy scale. The TOPSIS analysis use the decision matrix. To construct the weighted normalised rating, the criteria weight information was necessary. The FTOPSIS methodology can also be found in (T. Kaya & Kahraman, 2011) with data on how to use this methodology.

These criteria weights were previously generated using fuzzy AHP. The suggested method is helpful in determining the optimum energy source to employ. Another significant discovery is that this model accurately depicts the relative weights assigned to the various evaluation criteria.(Sadeghi et al., 2012).

Finding the ideal and unfavourable excellent options is made simple by this. As a result, comparing the Distance measures yields the preference order of the alternatives (Wang et al., 2008).

2.1.4 Elimination and Choice Translating Reality (ELECTRE)

ELECTRE methods are popularly used in energy planning. It preferred by the decision makers because of the broad perception they provide for the problem statement giving a practical view inculcating all the queries or suspicion(Kumar et al., 2017a). These methods are more preferred in applications related to the choice of allocating energy in demand side (Kumar et al., 2017a). ELECTRE is able to deal with quantitative or qualitative discrete criteria (Ilbahar et al., 2019). Grujic et al analysed 3 scenarios named realistic, optimistic, and BAU for energy sector development until 2030 for Belgrade (İ. Kaya et al., 2018b) . They used ELECTRE outranking method as a MCDM tool to obtain the best option for each scenario by evaluating alternatives in eight criteria (İ. Kaya et al., 2018a).

ELECTRE is a method for analysing the dominance relations among alternatives based on concordance and discordance indexes(Wang et al., 2008). All ELECTRE methods use an outranking method to solve problems and sort the alternatives by following two basic steps. The ELECTRE method allows the comparison of alternatives where there is no clear preference. Beccali et al. (2003) presented the Electre family of methods for ranking and classification problems. This method allows for direct comparison of branches without massive statistical inference. ELECTRE is a complicated algorithm that is difficult for most decision makers to understand. (Theodorou et al., 2010) This method can be used to solve decision problems with discrete criteria, but it is not necessarily complete. (Wang et al., 2008). The numerical administrative help of ELECTRE method is shown clearly with formulas in (Beccali et al., n.d.).

Since alternative strategies or measures examined typically do not come with thorough feasibility and/or environmental impact studies that would precisely specify the various impacts of the alternatives,(Lootsma et al., 1990a) ELECTRE III is a suitable MCDA method for energy planning due to the possibility of introducing thresholds. In the case of a pseudo-criterion, indifference extends to a region where the difference between a and a' is tiny, while a region of weak preference exists between the regions of indifference and rigorous preference, indicating a hesitation between the two.(Georgopoulou et al., 1997)

2.1.5 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) technique is an outranking method that was developed by Brans in 1982. PROMETHEE provides a complete ranking of alternatives from best to worst on the basis of certain criteria to obtain a preference degree from 0 to 1. As per (İ. Kaya et al., 2018a), PROMOTHEE has been used to analyse penetration scenarios of renewable energy alternatives in Greece, assess energy resources for electricity generation in Turkey (Önüt et al., 2008) and evaluate five alternative renewable energy scenarios in Austria. (Atici & Ulucan, 2011)

There are currently many MCDA methods that can be used in a wide range of decision circumstances (Løken, 2007; Lootsma et al., 1990b). The PROMETHEE approach was chosen for Greece case studies due to its

simplicity and ability to simulate how the human mind expresses and synthesises preferences in the face of numerous competing decision viewpoints (Diakoulaki & Karangelis, 2007).

This technique has a lower level of complexity as it is based on ranking and works effectively for issues where a limited number of activities must be evaluated according to a variety of competing criteria. It identifies alternatives, defines a set of criteria and evaluates matrix to find the most optimal solution.

Because of the quantity and variety of the things to evaluate, the unreliability of the data, and the disputes between interested parties, assessment procedures and energy planning may seem complicated. PROMETHEE provides a technical-scientific decision-support tool that can clearly and more important consistently defend its decision as the decision-making process for an energy project is the final step in the analysis and treatment of several information kinds, including environmental, technical, economic, and social information.(Cavallaro, 2009)

The created framework, which is based on the outranking method PROMETHEE II, emphasises the key structural features of the decision-making process and uses a deconstructed approach with regards to the best possible growth of RES. It was demonstrated that a method that unfolds stage by step is the most effective way to boost RES penetration because of their dispersed character and the inherent challenges connected with growth in isolated, agricultural areas. This method allows for the objective definition of PROMETHEE preference threshold values without the need for direct involvement from the analysts' group or the DMs. The sensitivity analysis is closely entwined with group agreement through its iterative process, although it does not always ensure a satisfactory outcome. (Polatidis et al., 2006).

PROMETHEE methodology was also used in ARTEMIS which can be studied in detail in (Kowalski et al., 2009). This method can also be modified with various other methods to find the optimum answer for a suitable case study as in (Oberschmidt et al., 2010).

2.1.6 Multi-Attribute Utility Theory (MAUT)

The MAUT approach is primarily used to assist decision-makers in better comprehending the problem (parameters, criteria, etc.). The fundamental phases in using this approach to arrive at the desired outcome are:

1. identification of the main purpose and the supporting objectives
2. identification of sub-objective qualities, evaluation of the scores and weights of the attributes, calculation of total utility (best option) using the scores and weights;
3. Analysis of sensitivity examines the effects of changing the value or weight of a characteristic on the utility as a whole.(Theodorou et al., 2010)

The main benefit of MAUT is that it accounts for uncertainty. It may be given a utility, which is a quality that is not often taken into account by MCDM techniques. It is thorough and can take into consideration and take into account each consequence's choices at each stage of the approach. Although this level of accuracy is practical, there are a number of potential drawbacks. This method is quite data heavy since a huge quantity of information must be entered at each stage in order to accurately capture the decision maker's preferences. Not every decision-making issue can be solved with this degree of input and data. Applications of MAUT in the fields of economics, finance, actuarial science, water management, energy management, and agricultural problems.

2.1.7 VIKOR Method

In order to balance overall and individual happiness, the VIKOR technique adds an aggregating function that quantifies departure from the ideal solution while taking into consideration the relative weights of all criteria. In contrast to ELECTRE, Huang and Yong's TOPSIS method and VIKOR methodology both rely on an aggregating function that denotes "closeness to the ideal" and originates from the compromise programming strategy.

The TOPSIS approach employs vector normalisation, the VIKOR method uses linear normalisation, and the normalised values are independent of the evaluation unit of a criterion. (San Cristóbal, 2011).

We can also look at the case of Istanbul where VIKOR and FVIKOR were used along with AHP methodology (T. Kaya & Kahraman, 2010a).

2.1.8 Grey Incidence Method (GIM)

Gray relation approach A subset of grey systems theory known as the grey relational technique was created in 1980 and has mostly been used to study MCDA issues in addition to energy systems. The grey relation method's guiding premise is comparable to TOPSIS. The method defines the grey relation degree to depict how similar the alternatives are to one another. Typically, the ideal option is identified, and the degree to which the alternatives differ from it is calculated. The weighted sum of its grey relational coefficients is then the grey relational degree. The option with the highest degree of relationship is closest to the best option while being farthest from the worst option. As a result, the best option is chosen based on the degree of grey relation (Wang et al., 2009).

2.1.9 Simple Multi-Attribute Rating Technique (SMART)

In 1977, Edwards introduced SMART, which he defined as the entire process of ranking alternatives and weighting criteria. The participants are asked to assess the significance of the changes in the criteria as they progress from the least favourable to the most favourable levels. The least important criteria is then given 10 points, and the remaining criteria are given progressively more points (without a clear maximum limit) to reflect their importance in relation to the least important criteria. By setting the sum of the points to one, the weights are determined.(Wang et al., 2009)

More examples of SMART method being used can be seen in (Jones et al., 1990).

2.1.10 MULTIMOORA Method

By comparing an alternative to all possible values of an objective, ratio system uses vector data normalisation. where wj is the weight of the jth criterion and x ij stands for the ith alternative of the jth goal, and j wj = 1. Absolute dominance is the state in which one alternative, one solution, or one project completely outranks all other alternatives, solutions, or projects in the same category. Thus, MOORA (i.e., the Ratio System and Reference Point) and the Full Multiplicative Form are summarised by MULTIMOORA. The Full Multiplicative Form, the Reference Point Approach, and the Ratio System.

With n being the number of objectives to be maximised and Bi = n j=g+1(xij) wj denoting the product of objectives of the ith alternative to be minimised, with n g being the number of objectives (indicators) to minimise, Brauers and Zavadskas proposed MOORA to be updated by the Full Multiplicative Form method, which incorporates maximisation as well as minimization of purely multiplicative utility function. (Streimikiene et al., 2012a)

2.1.11 COPRAS (Complex Proportional Assessment) Method

Zavadskas and Kaklauskas created COPRAS, an MCDM technique (1996). This approach makes the assumption that the importance and priority of the studied versions directly depend on and are inversely related to a set of criteria that adequately describes the alternatives, as well as the relative importance and weights of the criteria (Banaitiene et al. 2008).

The ratio to the ideal solution and the negative ideal solution can both be taken into account simultaneously using this method. In contrast to the negative ideal solution, the ideal solution minimises the cost criterion while maximising the benefit criteria. (Yazdani-Chamzini et al., 2013a)

2.1.12 Weighted Sum Method (WSM)

Several methods have been adopted throughout the literature to provide a comprehensive solution to the renewable energy problems. In the literature, AHP, ANP, ELECTRE and TOPSIS have come into the forefront as the most commonly used methods. The use of ELECTRE, TOPSIS and other MADM methods has also increased over the years although it is a lesser extent than AHP (Ilbahar et al., 2019).

2.1.12 BOCR Analysis

One of the challenges of using ANP is ability to determine criteria, especially for fields in which no similar applications have been applied. For these kinds of situations, another survey is generally implemented by using different methods such as SWOT, BOCR, which allows the ability to select the factors to examine. The challenge is that often in these instances, participants cannot come to an agreement regarding some points. The ANP with BOCR can be used to solve this kind of problem.

As concluded by (Rigo et al., 2020) in their research paper, there is a high concentration on using AHP to solve multi-criteria problems found in this area (64% in the weighting process and 37.7% in the evaluation alternatives process), followed by TOPSIS and ELECTRE (26.4% and 13.3% in the evaluation alternatives process).

Information is imperfect and tainted by subjectivities in very ill-defined decision environments, and it is challenging to determine the relative weight of each criterion. However, Multi-Criteria Decision Making (MCDM) methods provide ways to get around restrictions. A variety of criteria and sub-criteria that can be analysed and evaluated can be charted using MCDM approaches. These methods assist in identifying competing attributes, allocating and prioritising weight to attributes, ranking the alternatives, and determining the optimal course of action. These methods aid in enhancing decision-making quality and are straightforward, logical, and effective.

Subjective biases cannot be managed by conventional MCDM procedures. Fuzzy MCDM techniques are used in place of traditional MCDM techniques to help make objective decisions, reflect human judgement ambiguities objectively, and resolve uncertainties

1) A review of the green supply chain

The development of many related methodologies has recently increased, as seen by the GSS. It's interesting to note that these approaches can be divided into two main groups, solitary and integrated representations. In terms of the former, a model for selecting GSS focused at manufacturing factories was provided using fuzzy AHP (analytic hierarchy process). The VIKOR technique for collective SS was expanded with various criteria by using span two-tuple semantic data. K Govindan developed the "fuzzy trivial pattern," a method of decision-making with several measures, to select the best suitable eco-friendly supplier for businesses engaged in the production of plastic. Additionally, D Kannan ABL introduced a fuzzy TOPSIS-based framework for selecting environmentally friendly suppliers for an electronics industry in Brazil.

2) Chain of Renewable Energy (Masoomi et al., 2022)

According to a similar USA agency, supplies of RE can be replenished in contrast to the finite supply of fossil fuels. There are five sources of RE that are regularly used on Earth: wind, sun, hydro, geothermal, and biofuels, which include biodiesel, ethanol, and biomass. In the US, biomass (waste and wood) is a very important source of renewable energy. Shows data from 2018 on how much energy the US used for various purposes. The International Energy Agency (IEA) has instead identified five different ways to obtain renewable energy (RE) from oceans: waves, tidal power, marine streams, salinity, and heat gradients.

3) 3) Choosing the criteria

It was demonstrated in 1966–1990 that the most important SS measures were primarily connected to volume, price, value, and distribution. However, scientists also considered all conventional and ecological parameters for GSS. the procedures that have been proven effective through prior research and professional interviews. A brief description of the numerous GSS assessment measures that many academics in various fields have considered is also provided. In selecting green providers, additional factors must be considered.

4) Model Choice

The FST can cope with the errors that exist in experts' opinions. As a result, MCDM methods and FST are frequently combined to offer solutions to challenging difficulties relating to decision-making. Investigations into numerous studies on MCDM-related topics show that each method has its advantages and disadvantages when it comes to providing solutions to problems brought on by decision-making processes. Due to the nature of the problem, the created solutions are generally non-optimal; in fact, these solutions serve as compromises between a number of objectives. Numerous research findings point to the use of various representations or models for problems relating to decision-making across a range of academic inquiry domains. When constructing standalone energy systems, (Perera et al., 2013) mixes Fuzzy-TOPSIS with Pareto multi-objective optimization.

2.2 Steps in formulating the optimal Renewable Energy Policy

2.2.1 Selecting appropriate renewable energy

The first step in the formulation of any renewable energy policy would be to select the renewable energy most appropriate for the country or the firm as per its operations. Renewable energy technologies make indirect contributions like providing energy for education, cooking, space heating, and lighting (T. Kaya & Kahraman, 2010b). Many countries and states have implemented incentives like government tax subsidies, partial payment schemes and rebates over purchase of renewables in order to encourage consumers to shift to renewable energy sources (T. Kaya & Kahraman, 2010b) . As per (Yazdani-Chamzini et al., 2013b), one way of selection is to take into account two criteria namely power and operation & maintenance costs. Evans et al. (2009) employed sustainability indicators to assess renewable energy technologies. They indicators include price of generated electricity, greenhouse gas emissions during the full life cycle of the technology, availability of renewable sources, efficiency of energy conversion, land requirements, water consumption and social impacts (Yazdani-Chamzini et al., 2013b).

Although MADM methods have been extensively used in energy planning, a comprehensive approach that includes the details of the problem structuring, decision model construction, and analysis stages as well as expert opinions and real data is scarce (Topcu et al., 2019) .In this study, we assume all indicators – economic, socio-political, environmental and technological to be of equal importance given the same uniform weight in order to ascertain the renewable energy most appropriate for the sector, geographical region or demographic.

In this study, we found it prudent to review and cite examples of cities and countries in Asia, Eurasia and Europe that have energy requirements as well as constraints similar to India. Yi et al. (2011) developed an AHP method based on benefit, opportunity, cost, and risk (BOCR) in order to select sustainable renewable energy source for energy assistance to North Korea (Yazdani-Chamzini et al., 2013b). In Taiwan, (H. C. Lee & Chang, 2018) after conducting their own research with the help of different MCDM techniques believe that hydropower is the renewable energy that was developed earliest; its cost is lower, and the technology is mature which makes it the ideal renewable energy source. Turkey much like India is heavily dependent on imported energy resources. (Ertay et al., 2013) believe that wind energy would be the best possible alternative after carrying out extensive research predominantly employing MCDM techniques like MACBETH and AHP to determine the best alternative for a country like Turkey. As mentioned by (Çelikbilek & Tüysüz, 2016), the application of the proposed grey VIKOR method and also its integration with other grey based multi-

criteria methods can be a promising area for interested researchers.. From an environmental, technological and socio-political standpoint wind energy is the best alternative for Turkey and does not rank far behind while taking into account economic factors. A study published by (das Shabbiruddin & Professor, 2016) also concluded that wind energy followed by hydel energy would be most appropriate for India by observing the power consumption growth of the state of Maharashtra. The use of more than one method in the same application and the development of novel user-friendly methods are becoming popular and they are going to be the future trends in the field of energy planning (Neves et al., 2018) . As per (Strantzali & Aravossis, 2016), , the use of more than one method in the same application and the development of novel user-friendly methods are becoming popular and they are going to be the future trends in the field of energy planning.

2.2.2 Selecting the ideal renewable energy technology

India can only be a potential world leader in terms of renewable energy technologies if the government makes concerned efforts to eliminate inappropriate, inconsistent and inadequate policies that favour orthodox fuels and technologies that do not recognise the social, economic, political and environmental advantages of adopting renewable energy technologies (Streimikiene et al., 2012b). This is supported by a research paper published by (Streimikiene et al., 2012b) according to which the multi-criteria analysis showed that renewable energy sources-based electricity production technologies are to be preferred. To be specific, hydro and solar power systems were identified as the most sustainable, whereas wood CHP and wind power remained some positions behind (Nixon et al., 2013). The results among two decision models, HANP and AHP, have shown a normalised ranking priority of 23-25% for AD and gasification (Nixon et al., 2013). The AHP model ranked nine primary technologies in terms of overall benefits, with wind and solar–pv topping the list (Stein, 2013). RETs, such as MH, SP, biogas, and ICSs, have a significant role in the socio-economic and environmental development of rural Nepal (Sapkota et al., 2014).

(Mallikarjun & Lewis, 2014) utilizes a data envelopment analysis model for each end-use to evaluate the performance of each technology based on the three objectives. The second stage incorporates factor efficiencies determined by the DEA models, capacity limitations, dispatchability, and renewable penetration for each technology, and demand for each end-use into a bottleneck multi-criteria decision model which provides the optimal energy resource allocation (Mallikarjun & Lewis, 2014). This framework accommodates both the needs of users and regulators.

2.2.3 Focusing on optimal renewable energy production/generation

A study by (Kittur et al., 2016) discussed different MCDM methods such as AHP, TOPSIS, WP and SAW to determine for a particular day what time would be optimal for energy generation. Using AHP to validate all four weights, it was ascertained that the 5th hour of the day was most appropriate for optimally generating energy.

Looking at China which is similar to India demographically in terms of its population we see that it too largely imports energy resources and is the second highest consumer of energy behind the United States. A paper published by (J. Chang et al., 2003) states that in order to maintain sustainable development China should enhance its efficiency of in using conventional and nuclear energy. Of the different renewable energy resources, biomass energy played an important role in the energy budget of China and almost 20% of the primary energy consumed in China is biomass energy (J. Chang et al., 2003). Despite its massive usage, the

technology of biomass utilization is still in the development stage (J. Chang et al., 2003). A model presented by (Cong, 2013) focuses on maximising future generation of renewable energy (wind, solar and biomass) by optimal planning of investment in capacity, subject to a number of economic, social, political and environmental constraints. On the other hand, for the United States which is the leading consumer of energy resources, (Okioga et al., 2018) suggests prioritising utility-scale renewable electricity technologies at the regional and national levels as well as stipulating technology-specific renewable electricity targets for the U.S. to maximise electricity generation. This conclusion was made after developing regional and national renewable electricity portfolios with the help of AHP taking into account land requirement, location potential emissions, water demand and public perception as criteria.

A model proposed by (Cartelle Barros et al., 2015) assesses the global sustainability of different electricity generation systems and ranked wind as the most sustainable renewable energy generated in Turkey and Istanbul while the UK would do well setting up small solar photovoltaic systems. Finally, in the case of India (Sen & Bhattacharyya, 2014) ascertained that the most technically feasible and economically viable hybrid solution for off-grid electricity supply to a remote village such as Palari resulted in a least cost combination of small hydropower, solar PV, bio-diesel and batteries that can meet the demand in a dependable manner at a cost of $0.420/kWh

2.2.4 Optimising renewable energy supply

To combat Ghana's energy crisis, (Gyamfi et al., 2015) talks of how the former can be mitigated by effective deployment distributed generation technologies in strategic rural locations where resources are available but yet to be harnessed. Another way by which Ghana can improve supply of energy is by continuing to have diversification into renewables as a key policy objective of governance. While government policy commitment and policies in the past have not resulted in significant renewable energy installation, there are indications that the Renewable Energy Law to provide the necessary fiscal incentives for renewable energy development by the private sector (IPP), could result in the growth of the renewable energy industry over the next decade and beyond (Gyamfi et al., 2015) thus improving supply of energy not only for its industries but also rural electrification.

According to (Shen & Luo, 2015), China's adoption of renewable energy to improve energy supply has been hindered by obstacles such as high cost to develop, small segment to market, lack of legal means, weakness in the manufacturing industry and so on. These challenges can be met head on if the government were to introduce competitive subsidies that would help finance certain costs that cause firms not to adopt renewable energy. From a European perspective, (Fouquet, 2013) writes about hoe changing demand side management approach and energy service orientation would help improve adoption of renewable energies thus increasing supply while also contributing to pre-existing oligopolistic energy supply structures.

By taking the case study of an island, Porto Santo (Duić & da Graça Carvalho, 2004) state how adopting renewable energy can help increase security of supply and employment opportunities without increasing costs. Smaller in size, such islands can easily integrate renewable energies such as hydroelectricity and geothermal energy into already existing power generation structures and systems.

2.2.5 Efficient distribution of renewable energy

One serious concern in terms of energy is the distribution and transmission losses experienced which considerably deplete the energy that is generated. (Zeng et al., 2015) explores this conundrum in their paper wherein they discuss how resource distribution and technological levels of a country result in difficulty in grid connection. According to the paper which took the example of China, countries must first evaluate the planning and construction of renewable energy generation in their country followed by studying the operation management, organisation management and incentive policy prevalent. After considering the above-mentioned factors, a distribution management policy should be formulated keeping in mind the resource endowment, technological level and know-how as well as power system. In the context of Australia, (Wright, 2012) proposes setting up solar power plants in remote areas where space is not at a premium and similarly setting up wind farms away from densely populated areas to reduce opposition and concerns raised by people regarding high costs and rehabilitation. Moreover, investment is required in order to improve transmission networks to fully realise the benefit of renewable energies utilising numerous generators that can be well connected in time and with money. This would lead to economies of scale in the future with the new energy distribution system generation sizable returns. (C. ter Chang, 2015) talks about how location of plants is key in the adoption of renewable energies as location dictates total deviations from predefined goals concerning power generated, investment costs, emission avoided, jobs created, operation and maintenance costs, distance security and social acceptance. Lastly, use of distributed generation units may reduce losses associated with distribution and transmission through optimal placement at optimal location. (Bansal et al., 2021) have written a paper describing how TOPSIS can be used to do the same.

3. Research Methodology

This section presents the research methodology utilised to evaluate MCDM techniques for energy policy and decision-making problems. A total of 202 papers were evaluated and analysed during our research with only 63 papers mentioning “MCDM” as a keyword i.e., 31.19%.

The number of articles published from 1990 to 2022 are represented graphically in 5-year increments as seen in Figure 1. In research, we were able to find the year of publication for 196 research papers out of the 202 selected. The histogram considers seven time periods namely 1990-1995, 1995-2000, 2000-2005, 2005-2010, 2010-2015, 2015-2020 and 2020-2025. The highest number of research papers pertinent to our topic of research were 42 found in the time period 2000-2005. This was closely followed by 2010-2015 wherein 41 research papers were published regarding the topic. In the 2005-2010 increment as well as the 2020-2025 increment 30 papers were published related to the topic at hand. The 2015-2020 increment saw 25 research papers relevant to our research area. 22 research papers were taken from the 1995-2000 increment to carry out research. Finally, the least number of papers which were 5 in number were found to belong to the 1990-1995 increment.

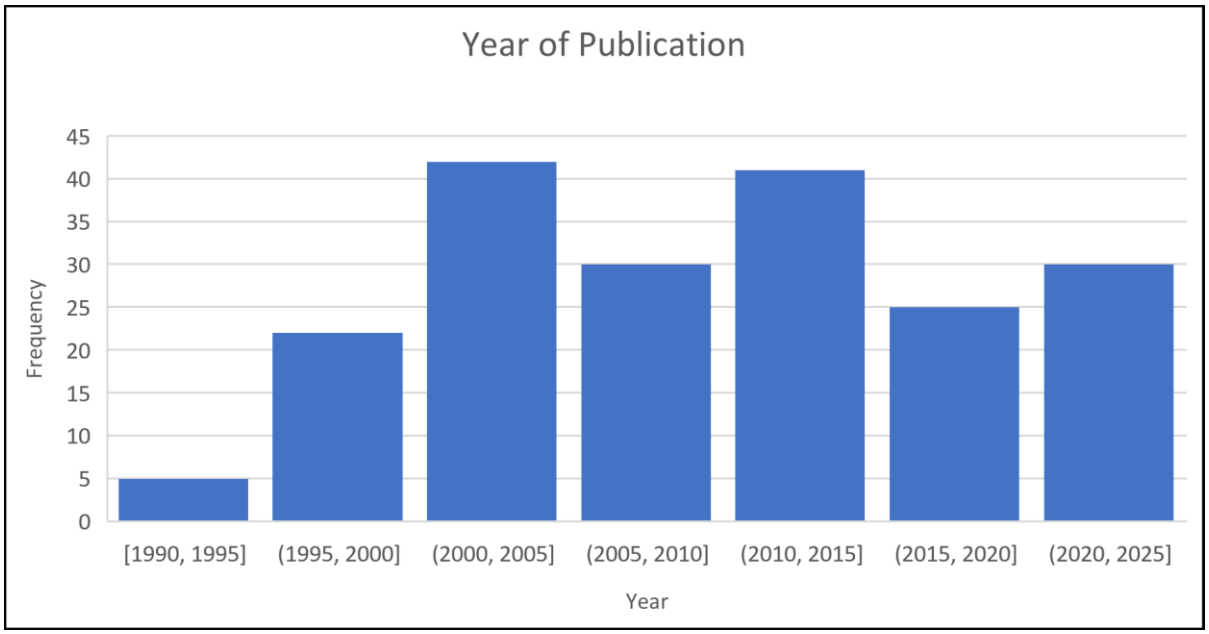

Figure 1: Year of Publication

Figure 2 represents the authors who published the most research papers in the area of MCDM and energy with the stipulation being that the authors selected must have written at least 3 research papers related to the topic. Benjamin F. Hobbs is at the top of the list having authored 7 research papers published pertaining to MCDM and energy. He is followed closely by Edmund Kazimieras Zavadska who has had 6 of his research papers published in relation to MCDM and energy. M. Ramchandran, S.D. Pohekar and Michelle L. Bell, each have published 4 papers related to our field of study. Lastly, Kaya and Abbas Mardani have both published 3 papers in relation to MCDM and energy.

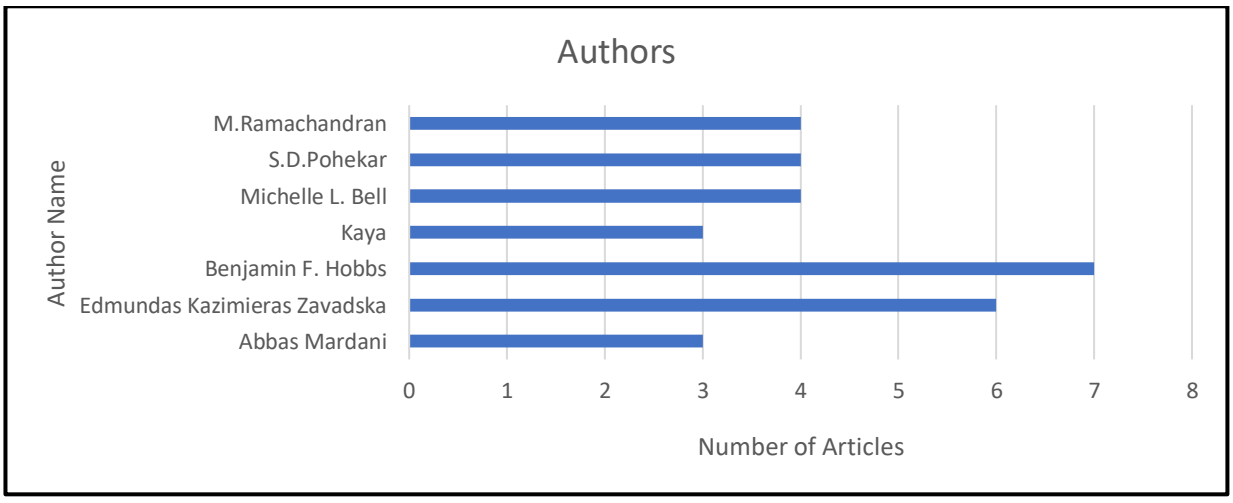

Figure 2: Research Papers published by different authors (N>=3)

38 research papers (18.81%) out of 202 research papers mentioned Analytic Hierarchy Process (AHP) in their keywords. While 7 research papers (3.47%) mention Analytic Network Process (ANP) in their keywords, 9 research papers (4.46%) mention the Technique for Order of Preference by Similarity (TOPSIS) in their keywords. 3 research papers (1.49%) mention Elimination and Choice Translating Reality (ELECTRE) in their keywords and 6 (2.97%) mention Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) in their keywords. Benefit, Cost, Opportunity, Risk analysis or BOCR is mentioned as a keyword in 5 research papers (2.48%). Finally, VIKOR and Complex Proportional Assessment (COPRAS) are mentioned as keywords in 6 (2.97%) and 3 (1.49%) research papers respectively. As per Figure 3, we can ascertain that Analytic Hierarchy Process or AHP is mentioned the most in research articles while the other two that follow it are TOPSIS and ANP.

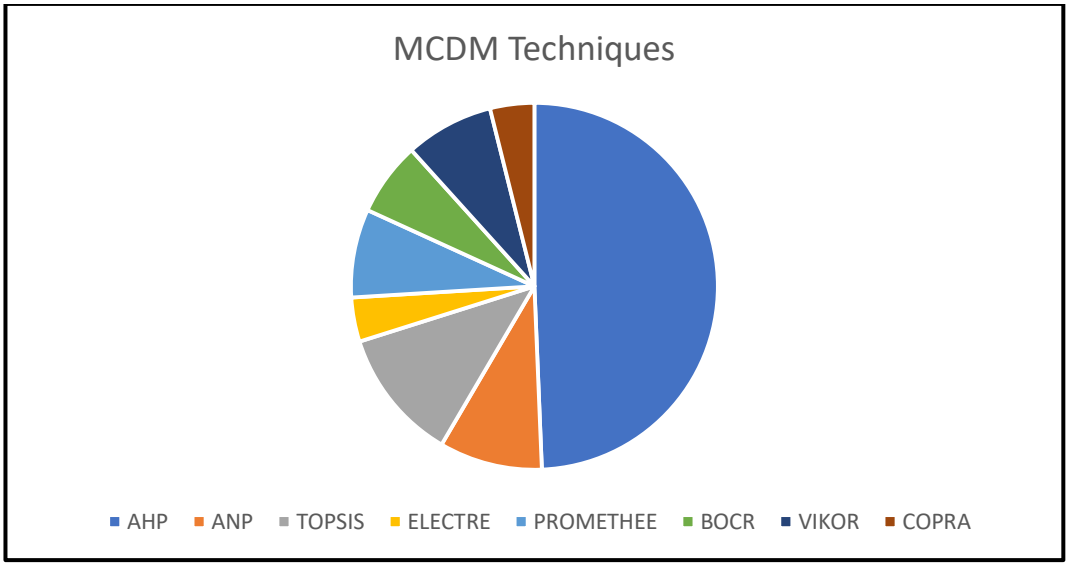

Figure 3: MCDM Techniques

4. Summary of the Review and Research Gaps

Figure 4 displays the keyword network obtained from the keywords utilised in each of the contributing research papers. It is evident that renewable energy, multi-criteria decision making or MCDM and Analytic Hierarchy Network or AHP are the top keywords. These are also followed by a slew of other keywords primary amongst which are sustainable energy and Analytic Network Process (ANP).

Meanwhile Figure 5, presents the citation network of selected contributing papers based on authors. One can clearly see that Edmund Kazimieras Zavdskas has contributed the largest number of articles to our area od study followed by authors such as Dalia Streimikiene and Abbas Mardnai.

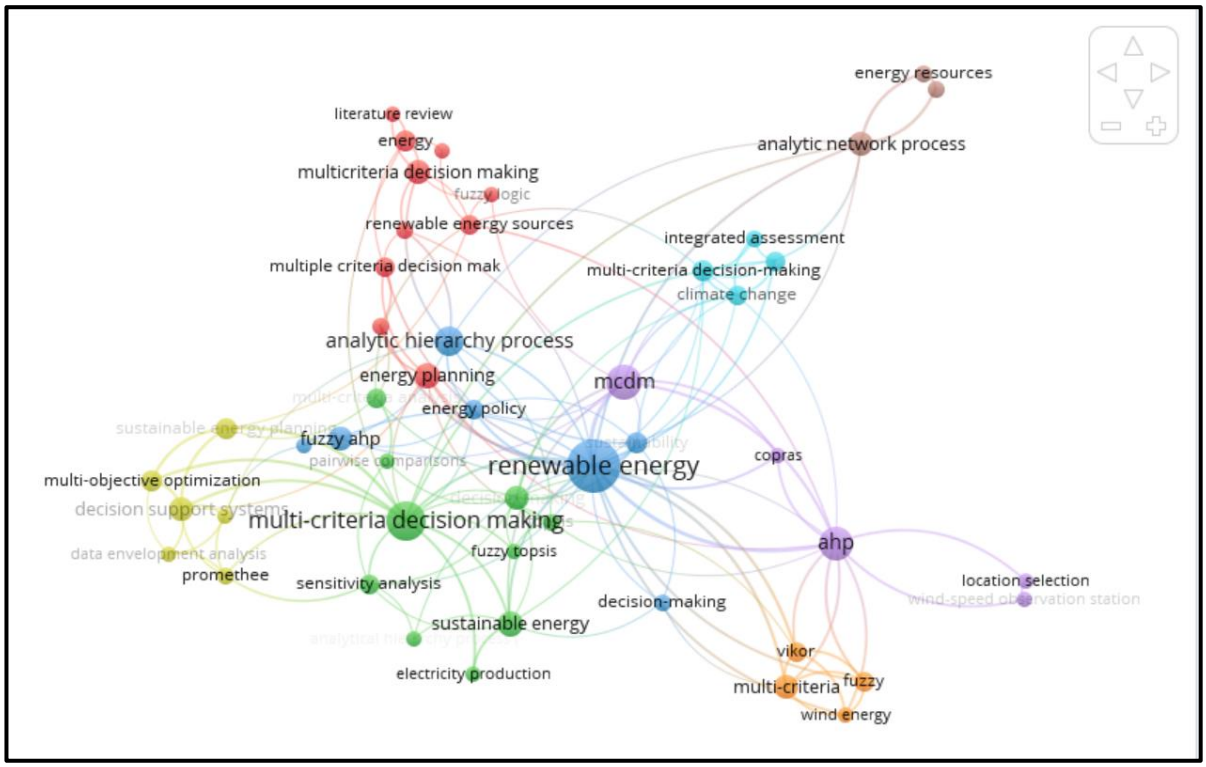

Figure 4: Citation Network of Keywords of Research Papers referred to (Source:VOSviewer)

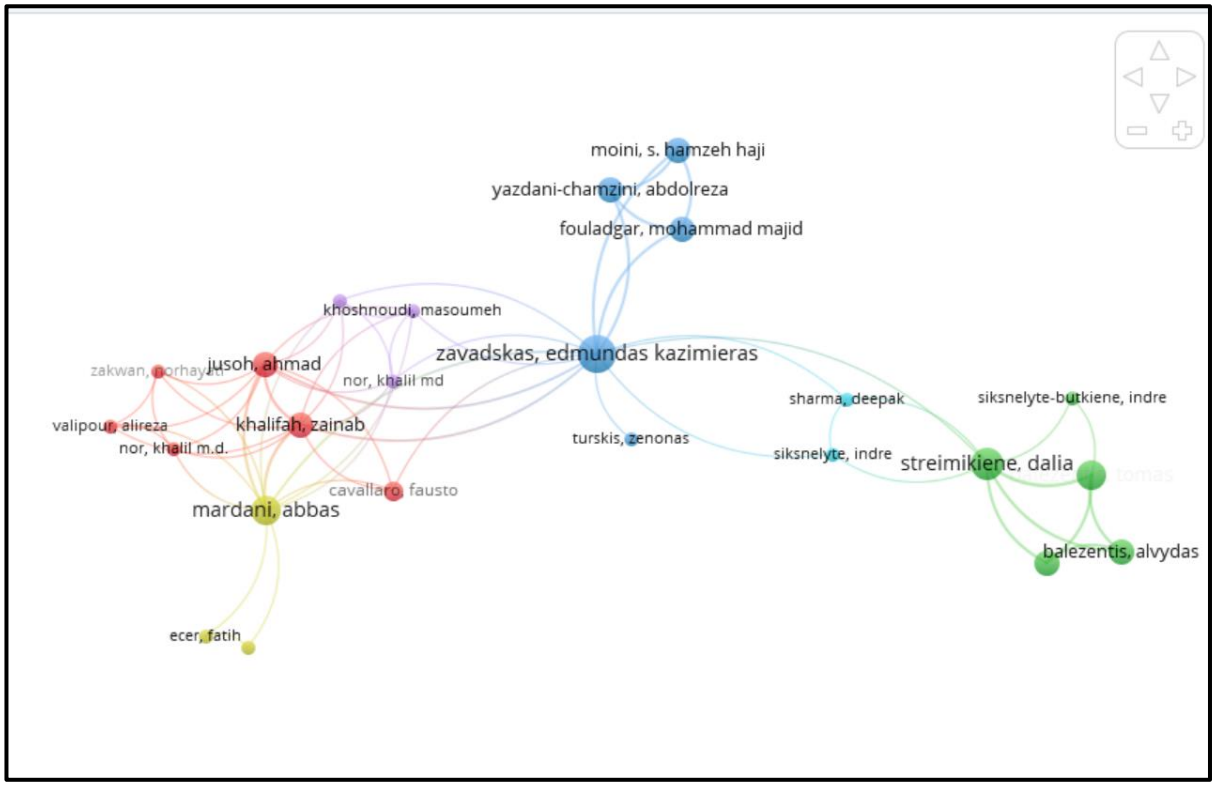

Figure 5: Citation Network of Authors referred to (source: VOSviewer)

Firstly, Section 2 described the different MCDM techniques in play that can be used in order to review and create Renewable energy policy and solve decision-making problems. Most studies related to solving issues related to an energy crisis were mainly concerned with and took into account AHP, ANP and TOPSIS. Our research paper endeavoured to look at a greater number of MCDM techniques that could be used in energy policy and decision-making namely AHP, ANP, TOPSIS, VIKOR, PROMETHEE, ELECTRE, MAUT, GIM, SMART, MULTIMOORA, COPRAS, WSM and BOCR analysis.

Secondly, in our study we have chronologically reviewed and organised multiple papers tracing a timeline from 1990 to 2022 to create a more comprehensive research paper and show how the development and use of MCDM techniques as well as their application in energy policy formulation has evolved over the years. While AHP, ANP and TOPSIS have been historically used in the field of energy, recent years have also seen these techniques supplemented by VIKOR and PROMETHEE amongst many others.

Thirdly, our research examines the usage of green and renewable energy methods by important nations across time, demonstrating a consistent rise in public awareness of renewable energy worldwide. We discussed a variety of sustainability topics. There are few research that compared the outcomes of various MCDM approaches. The majority of the research used standalone or combined MCDM techniques to explain their findings. We employed an ideal mix of in-depth examination of more than 10 various MCDM methodologies distributed equally over the years. The influence of green and renewable energy on a nation's economy and future was largely ignored in earlier writings. We have demonstrated the beneficial effects of employing renewable energy using a methodical MCDM methodology and the overall benefits to society.

Fourthly, according to Liou and Tzeng, MCDM methods typically take into account irrational assumptions in real-world problems, such as the criteria's independence, linear aggregation, or the provision of the best alternative among various alternatives rather than the alternative that satisfies the aspiration levels. The TOPSIS approach, according to some authors, cannot be utilised for ranking or selection. In an illustration, Opricovic and Tzeng compared VIKOR and TOPSIS and demonstrated that the greatest option isn't always the one that comes the closest to the ideal according to TOPSIS. After analysing the fuzzy TOPSIS proposed by Kuo et al., Wang et al. further claimed that TOPSIS cannot be used for ranking purposes. Concerning criteria weights, it may be challenging for a group of DMs to give precise criteria. A group of DMs may find it challenging to give precise criteria weights because there are so many factors that could affect how accurate their subjective weights are. For this reason, Hatefi added that although there are a limited number of objective or semi-objective techniques in this field, such as entropy, standard deviation, ideal point, and maximising deviation, analytical techniques are still required to handle circumstances in which there is a lack of preferences data from DMs. It is illogical for DMs to set criteria weights based on their knowledge because they are typically chosen from diverse disciplines with a variety of abilities, knowledge, and experience.

Lastly, we carried out in-depth research regarding the use of MCDM techniques in renewable energy and how they are revolutionizing the energy industry on the basis of 202 research papers that had been published previously. The research paper also enabled us to understand in depth the transportation problem we solved

along with our assignment. Furthermore, we also learnt about the installation of more solar energy resources that will be immensely useful in the understanding of our next paper on Installation of Solar Panels.

5. Results and Discussion

Findings revealed the following important aspects of previous studies.

i) Most of the research applied and built on pre-existing research centred around Analytic Hierarchy Process, Analytic Network Process and The Technique for Order of Preference by Similarity and their application in different countries to see how it would apply to a global scenario.

ii) In recent years, renewable energy has been at the forefront of every country's decision-making policy regarding sustainability and resource allocation. In several years, many alternatives and upgradations to pre-existing techniques have taken place such as Fuzzy-AHP or integrating TOPSIS with GIM.

iii) By rating energy sources, energy technologies, and energy projects in accordance with different goals, aspects, and criteria, the application of MCDM approaches to these challenges offers a trustworthy solution strategy. The pairwise comparison based methods (AHP and ANP), distance based approaches (TOPSIS and VIKOR), outranking methods (ELECTRE and PROMETHEE), and other ways are appropriate categories for classifying MCDM techniques utilised in decision-making situations (DEMATEL, Choquet Integral, Grey, etc.). The weights of evaluation criteria are typically calculated using the AHP and ANP approaches. In reality, integrated MCDM techniques using two or more techniques are frequently used to solve energy decision-making issues.It is evident that energy policy and decision-making issues can be successfully addressed by MCDM methods and its hybrids.

iv) Solar energy is not only twice as effective as any other type of energy but is also one of the most effective, prominent and essential source of energy out there as of this moment With the right allocation and distribution of this energy not only can natural light usage be maximized but also will reduce our reliance on other sources. Planning the exact area of installation is also really important. .Thus, the use of solar energy should be increased and this would help in both cost-cutting as well use of natural resources of energy.

v) Management and distribution of the energy available needs to be done with proper execution as improper or missing details may lead to the unavailability of energy. In future, it is suggested to involve managers of the enterprises and local members of the public in the valuation process to make more reliable results for the selection of the optimal bioenergy production technology.

6. Conclusion and Future Work

This paper presented a literature review on MCDM methods applied in different dimensions of energy policy formulation and decision-making problems. Although there have been many papers published in the area of MCDM techniques in and of themselves, there are very few systematic literature reviews published. A systematic literature analysis and review to identify applications of MCDM techniques in energy policy formulation was lacking. Contributing to the academic discussion on this topic, this is the first effort to review a multitude of MCDM techniques and tailoring their attributed to create the optimum energy plan concerned with source selection, technologies, planning, production or generation and distribution.

We can infer that experts think the greatest method to strengthen a nation's energy security is to give the technological and financial benefits of renewable energy the highest priority. The future selection of renewable energy alternatives can be guided by the MCDM technique, which can help to identify prospective advantages and possibilities as well as likely costs and dangers. We discovered that solar and wind energy would continue to rank top and second in the event of significant disruptive occurrences.

The main aim of this work to present a new approach using MCDM under rough number sets. With more and more countries adapting to the use of solar energy and installing solar energy plants, the use may as well be as maximized as the availability. While the pandemic has brought development opportunities to renewable energy, it has also exposed issues regarding renewable energy efficiency, renewable energy security, renewable energy subsidies, etc. In recent years, IES has widely developed around the world to provide multi-type energies and improve the energy efficiency. It is of great significance to identify, analyse and evaluate the risks of IES projects so as to provide a reasonable planning option for decision makers. The benefit of the method used is that it helps decision makers to recognise the most significant parameters creating vulnerabilities (or successful conditions) for the studied technologies. Thus, overall, this study provides policy decision making with an evaluation for positive energy communities and suggests the SDHS integration to meet the global sustainability goals. This study aims at the development of decision-making framework for the efficient selection of resource-exhausted transformation template by shaping it as an MCDM problem. Future extension and developments for refinement of the presented energy access planning framework are suggested. However, a comprehensive assessment on technical, economic, social, behavioural and commercial issues need to be investigated. As a result, decision support methodologies, such as the one presented in this paper, are needed to identify, diagnose and order the appropriate actions in a consistent way, as well as to assist policy making and formulate a modern energy companies' operational environment. While both modelling approaches provide valuable insight into energy networks, they do so from different perspectives. Thus, we can conclude that use of solar energy in the near future is only going to be more extensive and will continue to increase. It will not only benefit the people but also the environment as only natural resources are being used.

In conclusion, we would like to acknowledge some study limitations and propose some future research directions. At present the study has been limited to two databases: ScienceDirect and Google Scholar. Therefore, potential additional resources can be scoured such as conference proceedings or books not indexed in either of the two databases in order to have a deeper understanding of the topic. Further, the research was limited by the fact that all papers reviewed were in the English language which barred us from considering contributions in other local languages. Additionally, there is emerging but limited information regarding alternatives to pre-existing MCDM techniques and upgrades to the same. New and improved techniques could help create dynamic models to optimise the field of energy policy formulation and planning.

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