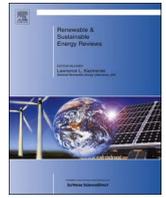




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## A review of multi-criteria decision-making applications to solve energy management problems: Two decades from 1995 to 2015



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### ABSTRACT

Energy management problems associated with rapid institutional, political, technical, ecological, social and economic development have been of critical concern to both national and local governments worldwide for many decades; thus, addressing such issues is a global priority. The main objective of this study is to provide a review on the application and use of decision making approaches in regard to energy management problems. This paper selected and reviewed 196 published papers, from 1995 to 2015 in 72 important journals related to energy management, which chosen from the “Web of Science” database and in this regard, the systematic and meta-analysis method which called “PRISMA” has been proposed. All published papers were categorized into 13 different fields: environmental impact assessment, waste management, sustainability assessment, renewable energy, energy sustainability, land management, green management topics, water resources management, climate change, strategic environmental assessment, construction and environmental management and other energy management areas. Furthermore, papers were categorized based on the authors, publication year, nationality of authors, region, technique and application, number of criteria, research purpose, gap and contribution, solution and modeling, results and findings. Hybrid MCDM and fuzzy MCDM in the integrated methods were ranked as the first methods in use. The Journal of Renewable and Sustainable Energy Review was the important journal in this paper, with 32 published papers. Finally, environmental impact assessment was ranked as the first area that applied decision making approaches. Results of this study acknowledge that decision making approaches can help decision makers and stakeholders in solving some problems under uncertainties situations in environmental decision making and these approaches have seen increasing interest among previous researchers to use these approaches in various steps of environmental decision making process.

### 1. Introduction

Energy management decisions generally are complicated procedures, incorporating multiple knowledge bases such as social, physical, technological, political, and economical. For the human health assessment, the risks related to ecological issues accompanied with environmental stressors, and the effects of some strategies on the decrease of risks, energy management decision makers generally make use of several computational models, experimental tests, and tools. For three different reasons, using these computational models, experimental tests, and tools are difficult. First, many risks are emerging (for example, climate change, life cycle assessment, life-cycle cost analysis, environmental risk perceptions, and human health risk assessment). There is insufficient information for managing these risks, and there-

fore decisions are made with a considerable degree of uncertainty. Second, in cases in which there are several traditional stressors and situations in regard to the same measure (e.g., risk), multiple lines of evidence exist; however, this evidence might point to multiple management alternatives. Finally, while the application of these tools for those stakeholders who are interested in particular courses of action gain increased access to all available information, due to uncertainty of data, they can justify contradictory courses of action. Therefore, to integrate heterogeneous and uncertain information, there is a need for expert judgment and a systematic framework to organize the technical information. Multiple criteria decision making (MCDM) provides a systematic methodology that aids decision makers in combining these inputs with the benefit/cost information and the stakeholders' perspectives in order to rank all alternatives of projects. MCDM illumi-

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nates 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. Under the umbrella of MCDM, there are many approaches, each of which involves various protocols to elicit the inputs, structures for representing them, algorithms for combining them, and processes for interpreting and using formal results within real decision-making or advising contexts.

The literature on energy management is steadily growing, covering a variety of interpretations and implementations. At the time of decision making, decision makers attempt to select the best solution. Indeed, a truly best solution can be obtained from a single criterion which is taken into consideration. In most actual decision-making procedures, it is not sufficient to make a decision based on only one criterion; rather, a number of inconsistent and non-commensurable objectives must be taken into account. As a result, a genuine optimal solution that would be optimal for all of the DMs who are subject to each of the considered criteria [1] cannot be found. MCDM is applied in situations which have contradictory criteria to help individuals make decisions in accordance with their preference [2]. MCDM associated with complicated difficulties over breaking difficulties into slighter portions. After making decisions and considering the issues about the slighter mechanisms, the problem portions are reconstructed to represent an inclusive view about the DMs [3].

DMs apply the MCDM approaches and techniques in order to organize and synthesize the collected information so they can feel confident and comfortable with their decisions. Using MCDM approaches and techniques, DMs must properly account for all significant criteria, which helps to decrease post-decision regret [4]. MCDM approaches and techniques can be used to determine vital principles about problem and evade creating important conclusions out of a routine. A great quantity of MCDM methods and practices were offered in the related studies recently [5]. The approaches and techniques are different in many aspects, including the kind of inquiries examined, the theoretical background, and the kind of outcomes [6]. MCDM approaches are suitable for energy systems since energy systems are subject to long time frames, sources of uncertainty, and capital-intensive investments [7], as well as featuring numerous DMs and several contradictory criteria. For the selection of MCDM approaches and techniques, several criteria should be considered. The key is finding a method for measuring what is supposed to be measured (validity). Various methods likely lead to various results; as a result, a method reflecting the 'true values' of the user in the best possible way must be selected. Additionally, the method must provide all necessary information for DMs. There also should be compatibility between the method and available information (suitability). Furthermore, the approach should be easily understood [5]. When DMs cannot understand how a methodology works on the inside, they see the methodology similar to black box. It might lead DMs to distrust recommendations given by the MCDM approaches and techniques. In such cases, time should not be spent on this method. Some previous papers reviewed the role MCDM techniques in several areas such as service quality [8], transportation [9], economy [10], TOPSIS [11], renewable and sustainable energy [12], fuzzy MCDM [13], classical MCDM [14], quality management [15], VIKOR [16], tourism and hospitality industry [17], saving energy [18], sustainable supply chain management [19]. This review paper aims to provide review of multi-criteria decision-making applications to solve energy management problems. Few of previous studies reviewed the multi-criteria decision-making applications in energy management problems [12,20,21].

The remainder of this paper is organized as follows. Section 2 provides an overview of literature of energy management and MCDM and fuzzy MCDM (FMCDM). Section 3 explains the method and the process of this paper. Section 4 presents results and findings of this paper based on the study aims. Section 5 of this paper attempted to discuss on the obtain findings and results and Section 6 provides some conclude remarks, limitations of this study, and suggestions for future papers.

## 2. Literature review

Energy management problems, associated with rapid social and economic development, have been of critical concern to both national and local governments worldwide for many decades [22]. Increasing numbers of energy issues can lead to a variety of impacts on and liabilities in public health and sustainable regional development; additionally, energy problems can affect economic growth [23]. With the demands of both the advancement of regional development and the need to raise public awareness of energy problems, increasing pressures are being imposed on planners and decision makers for a more robust response to a number of energy concerns. Consequently, the identification of decision protocols with sound environmental and socio-economic efficiencies is desirable in order to promote effective energy management practices. A number of factors need to be considered by the planners and decision makers in environmental management systems, such as social, economic, technical institutional and political issues, as well as environmental protection and resource conservation. The complexities involved in generating the desired environmental management decisions may be exacerbated by uncertainties existing in the related system components. Moreover, such uncertainties and complexities may be further amplified not only by interactions and dynamics among various sub-systems but also the potential for economic penalties.

In many energy management problems, a number of criteria and/or objectives have been considered, leading to the development of multiple criteria and objectives decision-making approaches [24]. Haimes and Hall [25] developed an analytical and operational multi-objective framework, in which sensitivity, stability, risk and irreversibility as objective functions were considered, and a surrogate worth trade-off method was proposed to solve a multi-objective problem. In past decades, many efforts were undertaken to clarify the concept of energy management development and to develop related theoretical/practical options. Currently, the challenge has shifted to designing and stimulating processes of effective planning and decision making at all levels of human activity in such a way as to achieve local and global sustainable development [26]. In order for decision makers to gain insight into the complicated inter-relationships between the energy management practices, and to address the need for determining strategies to maintain eco-environmental sustainability [27], integrated environmental system analyses that comprise simulations of socio-economic behaviors and environmental processes, optimization of resource allocation, and analysis of associated uncertainties [28] is necessary. Moreover, no matter how deeply people understand an energy problem and how great a solution to the problem is designed; such a decision will not really come into effect unless it is agreed upon by multiple stakeholders involved in the decision-making process. Consider the example of climate change—humans already well understand the underlying mechanisms behind climate change and have developed good strategies to cope with this problem.

For a long time, DMs have been interested in energy systems using MCDM and how these methods have solved complex problems regarding energy management. In conventional single criteria decision making, the aim is to maximize benefits and minimize costs. MCDM, on the other hand, helps elucidate inherent features of the problem, to support the participants' role in the decision-making process, to help understanding of the analysts' and models' perception in a practical scenario, to facilitate compromises and collective decisions, and to enhance the quality of decisions through making them more rational, explicit, and efficient. The use of these methods causes factors like negotiation, quantification, and communication to be facilitated. MCDM approaches and techniques are used with decision-making processes in which there are multiple objectives. DMs have to select from among multiple quantifiable or non-quantifiable criteria. Generally, objectives are inconsistent with each other; as a result, a solution depends upon the preference of the DM. In most cases, various

groups of DMs are involved in the decision-making process. Each group provides various points of view and criteria, which are then resolved in a framework of understanding and mutual compromise. MCDM can be applied to a number of areas, for example, integrated renewable energy systems [29], sustainability assessment [30], strategic environmental [31], off-grid electricity supply [32], and sustainable energy [21].

### 3. Research methodology

For our research methodology, this review paper proposed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) provided by Moher, Liberati [33]. PRISMA statement has two main parts including systematic reviews and meta-analyses. Systematic reviews provide objective summaries of what has been written and found out about research topics. This is especially valuable in wide research areas, where many publications exist, each focusing on a narrow aspect of the field [34]. Systematic reviews aim to provide a full overview of research conducted on a specific field until the present date. All research procedures have to be made explicit before the actual conduct of the review to make the process objective and replicable. Meta-analysis presents a means of mathematically integrating findings employing diverse statistical approach from diverse of previous articles. In this kind of synthesis, primary studies that are compatible in their quality level are selected. This may help and highlight different facts which individual primary studies fail to do, e.g. it may prove that results are statistically considerable and important when small primary studies provide questionable and uncertain results with large confidence interval [35]. The main goal of PRISMA statement is to help researchers and practitioners for completing the report of clear literature review [36].

Several of previous studies have been conducted PRISMA statement in various fields to collecting a comprehensive literature review [36–38]. In our review study, for conducting of PRISMA method, we accomplished three main steps including: search in literature, choosing the eligible published papers, extraction of data and summarizing [39].

#### 3.1. Literature search

In this step, we have been nominated Web of Science database to present a comprehensive application of MCDM techniques to solve energy management problems. The literature search was accomplished based on various keywords such as: “energy management, environmental management, MCDM+ energy management, MCDM+ water resources management, MCDM+ renewable and sustainable energies, MCDM+ economic energy, MCDM+ eco-efficiency etc.) in addition, energy performance+ MCDM and clean energy, MCDM+ sustainability assessment, MCDM+ green management, waste management, MCDM + land management” and different MCDM approaches. We attempted to collect the current published papers were from 1995 to 2015. In total; 265 scholarly papers were extracted according to our strategy search. In the next step we identified and screen articles related to MCDM and energy management fields (n=237), then, we checked the duplicated papers with redundant information and after this step 225 paper were remained, we removed 12 records due to duplicates, after this step, we screened papers based on titles and abstracts and irrelevant papers were removed and in total 197 of potentially related paper were remained (see Fig. 1).

#### 3.2. Articles eligibility

In this step of review, for the purpose of eligibility, we reviewed the full text of each manuscript independently which extracted from last step. In the last step, carefully we identified the related articles to attain a consensus. Articles which had used MCDM techniques to solve energy management problems were chosen. Book chapters, unpub-

lished working papers, editorial notes, master dissertations and doctoral theses, textbooks, non-English papers were excluded. For evaluating of energy management problems; several of previous studies have used other methods such as optimization models and soft computing approach which, in this step also we excluded those studies. In the end, we selected 196 articles related to MCDM techniques and energy management problems, from 72 scholarly international journals and conferences between 1995 and 2015 which met our inclusion criteria.

#### 3.3. Data extraction and summarizing

In the final step of our methodology, after negotiation with other authors some required information was collected and finally 196 articles were reviewed and summarized. Application areas selected according to the Web of Science database and “Research Areas” and the articles which are refereed and have mainly occurring number of keywords. Journals that publish refereed articles names. In flowing; all selected articles were classified into different classifications including; environmental impact assessment, energy management, waste management, sustainability assessment, renewable energy, energy sustainability, land management, green management topics, water resources management, climate change, strategic environmental assessment, construction and environmental management and other energy management areas (see Table 2). In addition articles were summarized and reviewed based on various criteria such as; the authors, publication year, nationality of authors, region, technique and application, number of criteria, research purpose, gap and contribution, solution and modeling, and the last column presents comprehensive results and findings of each paper in which they seemed. We believe that; the reviewing, summarizing and classifying of articles can help us to achieve various critical and importance hints. Consequently, some suggestions and recommendations for future studies were proposed. Furthermore; we believe that; this review paper was accomplished very carefully and it presented a comprehensive source regarding the application of MCDM techniques to solving energy management problems. It should be noted that the main difficulty during using PRISMA method was about implicit expressing of methodologies in abstract and research method section of the selected articles. Thus, we required to go through the full content of articles and take a deeper look with more details to evaluate the exact applied approach for evaluating of energy management problems. Although it spent a considerable amount of time in selection step, it helped us to choose the most suitable publications in conducting this review.

## 4. Findings

#### 4.1. Distribution of paper based on MCDM approaches

Table 1 presented the MCDM and fuzzy MCDM approaches frequency of used in the energy management fields. Based on results and findings provided in this table, 196 previous published papers applied fuzzy MCDM and approaches. This table illustrated that hybrid MCDM and fuzzy MCDM approaches (27.92%) have used more than other approaches. In addition; AHP and fuzzy AHP approaches (24.87%) had the second rank. ELECTRE, fuzzy ELECTRE, MCDA and MCA approaches with 25 papers had the third and fourth rank (12.69%). Furthermore, TOPSIS, fuzzy TOPSIS, PROMETHEE and fuzzy PROMETHEE held fifth and sixth rank with 10 papers (5.08%). The frequencies of approaches are represented in Table 1.

#### 4.2. Areas of application

This study reviewed the main aspects of energy management field in MCDM theory and practice. The main purpose is to identify various applications for MCDM in the energy management topics and to

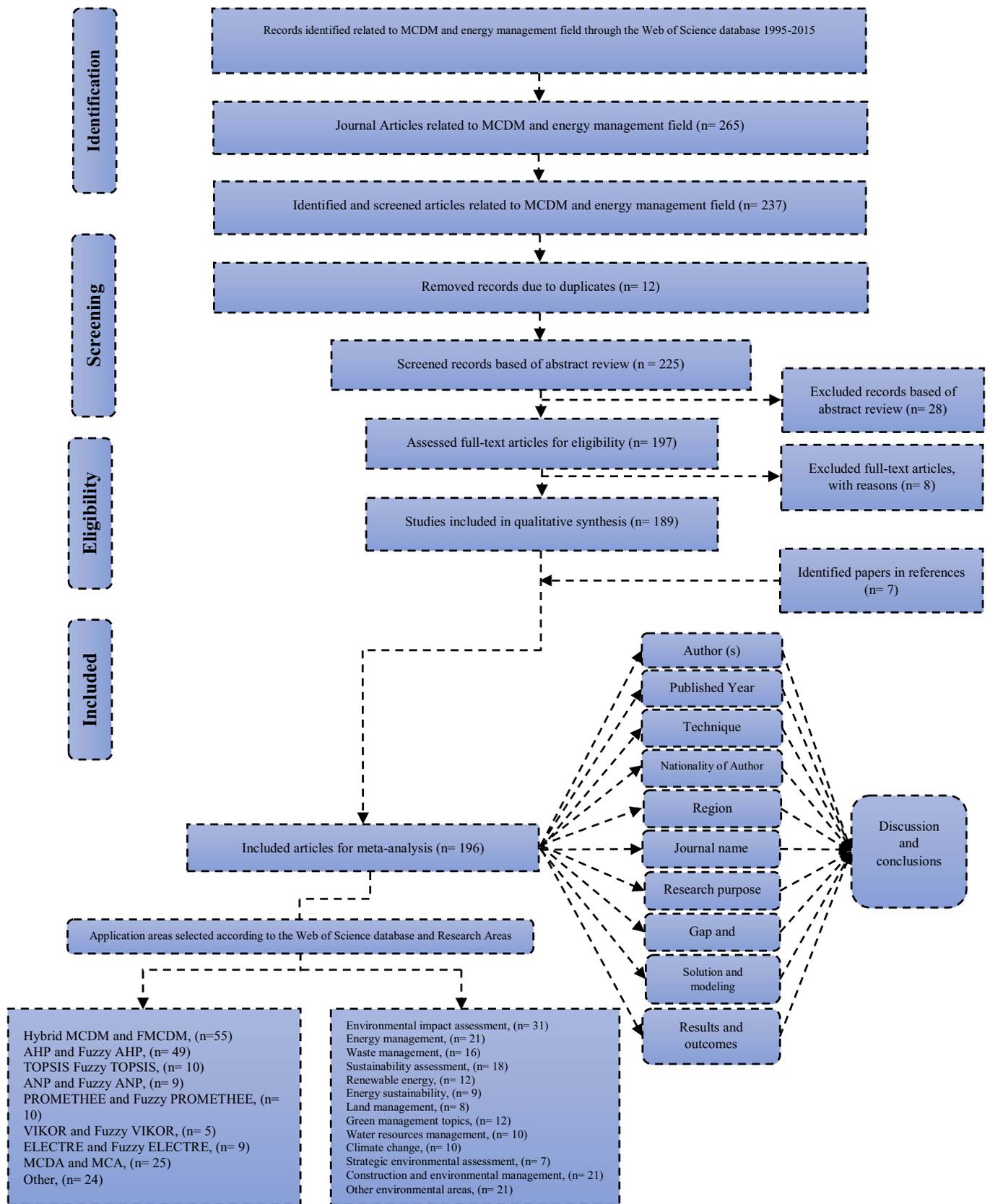


Fig. 1. Study flowchart for the identification, screening, eligibility and included of articles.

**Table 1**  
Summary of applications of the DM techniques.

DM techniques	Frequency of application	Percentage %
Hybrid MCDM and FMCDM	55	28.06%
AHP and Fuzzy AHP	49	25.00%
TOPSIS Fuzzy TOPSIS	10	5.10%
ANP and Fuzzy ANP	9	4.59%
PROMETHEE and Fuzzy PROMETHEE	10	5.10%
VIKOR and Fuzzy VIKOR	5	2.55%
ELECTRE and Fuzzy ELECTRE	9	4.59%
MCDA and MCA	25	12.76%
Other	24	12.24%
<b>Total</b>	<b>196</b>	<b>100.00%</b>

suggest robust and effective approaches for identifying the best solutions to complex problems. For example ANP approach used for various fields of energy management fields such as; strategic environmental assessment, land management, green management, climate change, construction and environmental management etc. The ANP approach is applied to assess flood risk management with these criteria, including economic, environment, safety and social concerns [40]. The MCA technique, used for socio-environmental assessment in shrinking cities with criteria of soil quality, hydrology, water balance, quality of green space, quantity of green space, green supply chain, population and infrastructure and additional sub-criteria [41].

In all selected papers, various approaches have been applied for numerous applications for solving problems related to energy management and identify and ranking the best alternatives. This review paper classified all selected paper in various application areas such as; environmental impact assessment, energy management, waste management, sustainability assessment, renewable energy, energy sustainability, land management, green management topics, water resources management, climate change, strategic environmental assessment, construction and environmental management and other energy management areas. In this regard, Table 2 showed distribution of selected papers based on various application areas.

Next sections present a systematic review and meta-analysis of the 196 papers, categorizing them into the 13 areas named above and sub-areas. All papers are then presented in tables, and each area of application is summarized based on the authors, publication year, nationality of authors, region, technique and application, number of criteria, research purpose, gap and contribution, solution and modeling, and the last column presents comprehensive results and findings of each paper.

**Table 2**  
Distribution papers based on application areas.

Application fields	Number of paper	Percentage (%)
environmental impact assessment	31	15.82%
energy management	21	10.71%
waste management	16	8.16%
sustainability assessment	18	9.18%
renewable energy	12	6.12%
energy sustainability	9	4.59%
land management	8	4.08%
green management topics	12	6.12%
water resources management	10	5.10%
climate change	10	5.10%
strategic environmental assessment	7	3.57%
construction and environmental management	21	10.71%
other environmental areas	21	10.71%
<b>Total</b>	<b>196</b>	<b>100.00%</b>

4.2.1. Distribution of papers based on environmental impact assessment

There are some methods which accepted for understanding of sustainable development such as environmental impact assessment (EIA). Sometimes, laws and local regulation are determined whether an EIA method is essential for evaluation influences of the projects. However, many stakeholders and shareholders have believe EIA method does not achieve acceptably in the practice [42]. The main EIA method criticisms are the limited attention on alternatives, systematically insufficient influence predictions, and the problems associated with concerning of shareholders and stakeholders in the significant and dynamic way as the products of exploration do not lead to clear understandings [43]. It seems that the concept of EIA is becoming mainstream at all levels of environmental decision making; therefore, previous scholars have studied how to solve these problems and in EIA they have applied DM techniques and approaches; the following are examples of how DM techniques and approaches have been applied: Josimović, Marić [44] applied a multi-criteria evaluation for waste management plans based on strategic environmental assessment; Wanderer and Herle [45] used AHP for assessment of environmental impact on energy; Massei, Rocchi [46] applied ELECTRE I, AHP and fuzzy set for assessment of environmental management model; Schetke and Haase [41] used MCA for socio-environmental assessment in shrinking cities; Kaya and Kahraman [47] assessed environmental impact by utilizing AHP and ELECTRE; [48] applied SAW, OWA and TOPSIS for assessment of environmental models. According to above literature and previous studies, Table 3 shows valuable distribution results of decision making approaches based on authors, nationality of authors, region, technique and application, number of criteria, research purpose, gap and contribution, solution and modeling, results and findings. Findings shown in this table indicate that 31 papers have employed fuzzy MCDM and MCDM approaches in the area of EIA. Findings of this table revealed that of the 31 published papers, AHP and fuzzy AHP mixed with other tools were used the most, followed by MCA and MCDA techniques. The findings shown in this table also revealed that four papers were published in 2014, four papers in 2013, and two papers in 2012.

4.2.2. Distribution of papers based on energy management

Energy management makes decisions on the production and dispatch of electric power and heat based on load profiles (both electric and heat), weather, price of electricity and heat, cost of fuel, environmental regulations, and local government policies. Thus, energy management encompasses all techno-economic issues that strongly impact efficiency in optimal investment planning in siting and sizing as well as in the technology selection of DERs that could bring the best PQR of supply to the customers at the optimal price. The objective of energy management is to attain economic feasibility, and so it has a broad role to play in the maximization of the above benefits [73]. Energy management is one of the most important topics of research in terms of global benefit. In energy management, energy consumption, environmental impact and cost efficiency are central to achieving successful sustainable energy management scenarios [74]. In recent years, numerous studies have attempted to identify suitable energy management opportunities among a variety of measures in order to achieve the energy saving targets in fields such as [75,76]. In addition, some previous scholars employed DM techniques and approaches to improve problems in this field such as Mourmouris and Potolias [77] employed MCDA for assessment of energy planning and renewable energy sources. Mourmouris and Potolias [77], evaluated the performance by fuzzy ANP, AHP and TOPSIS for building energy systems. Catalina, Virgone [78] analyzed energy systems by using ELECTRE III. Lee, Mogi [79] used FAHP and DEA for allocation of R & D resources based on efficiently energy, Polatidis, Haralambopoulos [80] integrated ELECTRE IV, PROMETHEE I and PROMETHEE II for a wind-hydro hybrid energy evaluation. Using data from above literature and previous studies about energy management area, Table 4 shows

**Table 3**  
Distributed papers based on environmental impact assessment.

Author	Nationality	Region	Technique and application	Number of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[44]	Serbia	Europe	Multi-criteria evaluation	11	Applied Multi-criteria evaluation for waste management plan based on strategic environmental assessment.	Need to adequate methodology for evaluation of waste management plan due to exist of several elements sustainable development which should be considered.	For implementing of Strategic Environmental Assessment (SEA) this study used the MCDM method.	Findings of this study demonstrated that; planning solutions evaluation was achieve zero state which from the sustainability aspect of waste management system.
[40]	Canada	Northern America	ANP	5	Applied ANP for assessment of flood risk management.	There is need to comprehensive MCA for assessment of water resources management and planning complex flood risk problems.	For assess of complex flood risk problems this study integrated MCA and DSS techniques.	Findings of this paper found that; the proposed integrated model can improve flood risk management and assessment under uncertainty.
[49]	Nepal	Asia	AHP	10	Used of AHP for develop environmental-economic framework.	Need to consider some criteria of sustainability such as environmental and economic in the area of lowland irrigated agriculture system.	For assess of sustainability criteria such as environmental and social this paper used GIS and MCDM methods.	Results of this paper indicated that, local and global priority and farmers' viewpoints among other sub-criteria.
[50]	Canada	Northern America	fuzzy AHP	45	Used FAHP for Risk-based environmental assessment.	Need to use MCDM tools for selection of criteria of risk environmental assessment due to conflicting and competing criteria.	Proposed new methodology to help DM under vagueness type uncertainty by using risk-based fuzzy AHP.	Results of this paper indicated that synthetic-based fluids (SBFs) were the most desirable choice, followed by fluids –water based fluids (WBFs) and oil based fluids (OBFs).
[51]	Australia	Oceania	MCAT	9	Employed MCAT for environmental investment.	Many of many natural resource management (NRM) problems have some social and ecological issues, so quantify of these issue is hard.	Proposed a novel tool called multi-criteria analysis tool (MCAT) for quantify the social and ecological issues in NRM problems.	Outcomes of proposed tool can help to improve the analytic rigour, transparency and auditability related to investment decisions.
[52]	Australia	Oceania	MCA	7	Evaluated the perception and learning of decision maker of MCA's overall usefulness.	Need to assessment of decision maker which used MCA for solving problems related to environmental projects in Australia.	Comparison between environmental projects which used decisions and unaided decisions in evaluation of their criteria.	Results of this paper indicated some decision maker which used MCA techniques were satisfy from these techniques, they would like to adopt these techniques for future improvement regarding to environmental problems.
[53]	Turkey	Europe	FAHP	6	Assessment of environmental and human health risk by used FAHP.	Ecosystem life quality is important issue for improve of sustain.	Proposed a new integrated model by using fuzzy AHP for assessment of human health risk and environmental criteria.	Findings of this paper found that; decision makers in environmental fields can apply this model by develop some alternatives of management for on-going and unfounded industrial plans by use hazardous materials.
[41]	Germany	European union	MCA	7	Used MCA for socio-environmental assessment in shrinking cities.	Nowadays planning of urban going to 'uncharted territory', therefore need to evaluate the influence of socio-environmental on shrinkage.	For solved this problem authors of this paper, finding land use and infrastructure changes relevance to demolition and vacancy, then, applied MCA for impact of socio-environmental urban residents and greenery.	Finding of this study indicated that shrinking The results show that shrinkage indicates some changes of socio-environmental in the residential livelihoods, though, does not basically decrease or increase urban quality of life overall.
[54]	Germany	European union	MCA	7	Used MCA for assessment of environmental targets into strategic urban planning.	Need to decrease the daily consumption of greenfield in Germany.	Proposed new MCA-DSS for assessment of sustainability and resource efficiency infill sites and greenfield.	Results of this study found that; develop greenfield sites usually displays less sustainability than that of infill sites.
[55]	Finland	European union	MCDA	5	Applied MCDA for integrating ecosystem services with assessment of environmental impact.	Lack of experimental stage in evaluation of ecosystem service (ES).	Used MCDA approach for employed and compared a desktop application of the ecosystem service (ES).	Outcomes of this paper demonstrated that, though integrating of ecosystem service (ES) with MCDA approach, can incorporating ecosystem service (ES) into EIA.
[45]	Germany	European union	AHP	2	Used AHP for assessment of environmental impact on energy.	Need to identify the better locations for implementing of solar power plants.	Proposed A web-based SDSS based on a MCDA approach for identify these kinds of locations.	Results of this paper found that, using of this proposed process chain can be applied for further assessment of environmental impact.

(continued on next page)

Table 3 (continued)

Author	Nationality	Region	Technique and application	Number of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[46]	Italy	European union	ELECTRE I, AHP and Fuzzy set	5	Applied ELECTRE I, AHP and Fuzzy set for assessment of environmental management model. Assessed environmental Index by utilized MCDA.	Value structure analysis of GIS is lower relevance to Spatial Decision Support Systems (SDSS). Using of some materials in creating a building has some impact on energy, socio-economic impact and environment, natural resource depletion.	For solving this problem author of this paper integrated GIS and MCDA for develop of Spatial Decision Support Systems (SDSS). Used MCDA approach for assessment of materials by developed the composite Environmental Index.	Results this integration help to understanding such unusual characteristics of MCDA-GIS integration. Results of this paper demonstrated that; some buildings which used non-fired materials were ranked higher compared to fire materials.
[56]	India	Asia	MCDA	9	Evaluated environmental impacts in aquatic ecosystems by using MCDA.	For improvement of decision making process, need to finding and assessing of the environmental impacts in aquatic ecosystems.	Applied MCDA and focus grouping techniques for strengthen the pluralistic concept.	Finding of this paper indicated that, it is social learning and representation conditions which should and encourage for optimal operation of MCDA method. Findings of this paper indicated that, due to of lack quantitative information the proposed approach can assess the environmental performance of suppliers.
[57]	Greece	European union	MCDA	3	Applied fuzzy TOPSIS for evaluation of environmental performance.	Evaluation of suppliers related to environmental performance is very important issue in recent years.	Proposed new fuzzy MCDM based on TOPSIS for assessment of supplier environmental performance.	Findings of this paper found that, the healthcare sector is the best alternative for assessing of the environmental performance of medical support service providers.
[58]	Canada	Northern America	Fuzzy TOPSIS	12	Used ELECTRE and VIKOR for evaluation of environmental performance.	Attention on the influence service supply chain on climate change is the very important issue in recent years.	Suggested the new integrate approach based of MCDM techniques for assessment of environmental performance in service supply chain.	Outcomes of this study indicated that; construction waste heavily impacts some criteria, thus rendering it noteworthy.
[59]	India	Asia	ELECTRE and VIKOR	9	Assessed environmental impact by utilized FANP.	Decision making on approval of EIA is very complex process.	Proposed the new integrated approach by using decision-support framework to operate the subjectivity as decision makers do in evaluating the values and facts.	Outcomes this study indicated that, the proposed model is successfully applied for EIA in Turkey.
[60]	Taiwan	Asia	FANP	10	Assessed environmental impact by utilized AHP and ELECTRE.	Environmental impact assessment (EIA) is the important issue due to both quantitative and qualitative factors	Proposed new integration approach based on AHP and ELECTRE for planning of urban industrial.	Findings of this paper indicated that, the proposed model can be use in real problem of EMS.
[61]	Canada	Northern America	FIS and FAHP	9	Evaluated the environmental management system (EMS) by applied FIS and FAHP.	How to ranking the environmental issue for creating of environmental policy is important problem in EMS.	Proposed new approach by integration of FIS and FAHP as robust tool for ranking environmental criteria in operations of OOG.	Findings of this study demonstrated that; COMPLEMENT as the proposed approach is workable with individual tools.
[62]	Netherlands	European union	AHP	5	Assessed environmental impact by utilized AHP.	Decreasing the emissions that cause an environmental problem sometimes lead to higher emissions cause another environmental problem.	Need to evaluate of environmental aspects in some business such national and international sectors.	Findings of this study found that; in field of biomass products there are less environmental impacts of biomass from some developing countries compare to the local forest.
[63]	Finland	European union	MCDA	26	Evaluated environmental impact by used MCDA.	There is lack in one stable methodology for weigh of relevance significant of diverse environmental impacts in LCA, while it should be important phase in Life Cycle Assessment.	Provided MCDA techniques for some weighting tools which can applicable in LCA process.	Outcomes of this paper found that, how the planning of combined the strategies of the by-product management in the steel and iron making industry can help by the use of flowsheet-based and MCDA based on support system.
[64]	Germany	European union	PROMETHEE	6	Assessed environmental system by used PROMETHEE.	Evaluation of production process under ecological, technical and economic perspectives need to specific approaches.	Presented model for assessment of eco-management by integrating of decision support system KOSIMEUS, flow-sheeting program and MCDA methods.	Outcomes of this study can help decision makers to achieve of the renewable energy alternative instead of fossil fuel.
[65]	Turkey	Europe	OWA operator	12	Used OWA operator for environmental assessment.	Nowadays consumption of fossil fuel is increased rapidly and this has negative influence on environment.	Using the renewable energies is the best alternative for replace on these kinds of fuels, so, this study used the DSS tool for selection of site for wind turbines by employs GIS.	energy alternative instead of fossil fuel.

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Table 3 (continued)

Author	Nationality	Region	Technique and application	Number of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[66]	Australia	Oceania	AHP	5	Employed AHP for evaluation of environmental problem.	Environmental management and natural resource are needed to improve the decision quality.	Used AHP based on world wide web for evaluation of environmental problems, this model called Java-AHP.	Outcomes of this paper found the Java-AHP is a tool which can use as individual and groups decision support system.
[48]	Germany	European union	SAW, OWA and TOPSIS	5	Applied SAW, OWA and TOPSIS for assessment of environmental problem.	Environmental problems are complex issue due to exist of several criteria.	Development of DSS tool for solving the environmental problems in water resource management.	Results of this paper indicated that, mDSS tool had the significant contribution on water resource management for WFD implementation.
[67]	Belgium	European union	MCDA	12	Used MCDA for assessment of environmental problem.	There are conflicts for environmental services due to diversity of stakeholders' motives related to formulate acceptable environmental policy.	For solving these conflicts related to environmental issues, this study proposed a novel methodology for enhances the acceptability of the group decision.	Outcomes of this paper found that; using SROAIs subsequently significantly can improve the tractability of the process.
[68]	New Zealand	Oceania	MCDSS	4	Employed MCDSS for evaluation of international environmental problems.	There are some lacks such as multi criteria based, transparent and decision support tool in the level of environmental problems.	Applied Multi Criteria Decision Support System (MCDSS) for improve these kinds of lacks in the international policymaking.	Finding of this paper demonstrated that, this tool was useful potentially and particularly in the early phases of policy development.
[69]	India	Asia	AHP	4	Used AHP for assessment of environmental impact.	Need to develop a conceptual algorithm for integration of optimal process into MADM procedures.	Proposed a novel methodology by combining of MADM and optimization procedures.	Results of this paper concluded that how combining of MCDM techniques with optimization procedures can be used as a tool for decision-making in EIA studies.
[70]	Slovenia	European union	AHP	4	Applied AHP for evaluation of wood products based on environmental impact.	Need to present a decision tool for classifying wood products on environment and whole life cycle.	Proposed new methodology based on multi attribute approach which including of the main criteria that impact on the burdening of environment.	Finding of this study found that; initial produce of energy consumption and auxiliary materials provided the main influence of wooden products on the environment.
[71]	Spain	European union	ANP	4	Evaluated EMS by employed ANP.	Due to reduce the environmental impacts firms need to adopt their environmental management systems.	Suggested a novel decision making approach based on ANP for assess and rank the criteria of environmental management system options in for-profit organizations.	Results of this paper showed that; all attributes of olive oil firms had the best intangible elements regarding to evaluating of the environmental management systems.
[72]	Germany	European union	PROMETHEE	14	Applied PROMETHEE for environmental assessment.	Regarding the worldwide changing of environmental policy need to assessment the production techniques.	Proposed an outranking methodology through integration of PROMETHEE and Life Cycle Assessment (LCA) for environmental assessment.	Outcomes of this paper can help to achieve insight into the preference structure of decision makers and to emphasis on critical issues regarding the soft decision analysis.

**Table 4**  
Distributed papers based on energy management.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[81]	Germany	European union	AHP	5	Utilized AHP for evaluation of crop rotations based on energy crops.	Need to find the future-oriented crop rotations which include the environmental and economic criteria for decision-making strategies.	Proposed a novel methodology by using AHP for evaluation of economic and environmental criteria regarding to assessment of crop rotations.	Finding of this paper demonstrated that, in the first step of evaluation some less global dimensions used for show how the crop rotations can gain the requirements of the defined mission statement.
[77]	Greece	European union	MCDA	17	Employed MCDA for assessment of energy planning and renewable energy sources.	In recent years there are some environmental and economic problems regarding rational energy planning, which is imperative to humanity.	Proposed the new evolutionary model for supporting of energy planning to promote the use of renewable energy sources.	Finding of this paper found that RE Sources exploitation in the level of regional can satisfy increase power demands related to through environmental-friendly energy systems which integrate biomass, wind power and PV systems.
[82]	Greece	European union	ELECTRE III	3	Employed ELECTRE III for decentralized energy systems.	There is lack for a specific criterion which describes the value of each renewable energy resources and there is no specific solution for optimization of all criteria of these resources in the same time.	For solving these problems, this present study applied ELECTRE III technique for scenarios of energy generation.	Results of this paper indicated that, environmental profile, stability and viability were the most important parameters.
[83]	Ireland	European union	MCDA	7	Assessed domestic electricity consumption and heating energy by used MCDA.	Need to the template which can evaluate the energy systems policy scenarios.	Proposed a new approach based on NAIAD for alternative electricity policy scenarios and domestic energy.	Results of this paper found that, MCDA based on NAIAD can measure based on quantitative and qualitative assessment.
[84]	Finland	European union	MAVT	5	Utilized MAVT for residential energy supply system selection.	Authors of this paper believed that selection of system related to residential energy supply is a MCDM problem.	Applied Preference Assessment by Imprecise Ratio Statements method as MCDM technique for selection of system related to residential energy supply.	Outcomes of this study found that, after comparison analysis of heating systems alternative, micro CHP from environmental perspective is reasonable alternative to traditional system.
[85]	Turkey	Europe	fuzzy ANP, AHP and TOPSIS	9	Evaluated of performance by fuzzy ANP, AHP and TOPSIS for building energy systems.	Need to novel approach in the construction sector due to an increasing rising energy prices demand for energy and efficiency in energy consumption.	Applied integrated MCDM technique for analyzing of the Building Energy Performance Calculation Methodology (BEP-TR).	Finding of this study indicated that, construction firms could identify which section can be ranking criteria for improve and enhance efficiency and effectiveness of their construction.
[78]	Romania	European union	ELECTRE III	3	Analyzed energy systems by used ELECTRE III.	Due to complexity and uncertainty of qualification and analysis of information data related to energy performance and economic criteria and influence on the environment evaluation approach needed.	For solving these problems related to energy systems this study applied ELECTRE III for analysis of performance in these kinds of systems.	Results of this paper found that, MCDM analysis can present some support related technical scientific which can rank alternative of renewable energy sector very clearly.
[86]	Greece	European union	ELECTRE III	5	Used ELECTRE III for modern energy formulation.	Need to develop the RES and the energy efficiency (EE) for enhance the operational performance in energy companies.	Suggested the new information decision support system, which involves of an expert subsystem, in addition to MCDM subsystem.	Outcomes of this paper found that for finding, classify and diagnose the suitable activities in the best way, to assist and help policy making and formulation of operational performance in modern energy companies.
[87]	China	Asia	FAHP	3	Employed FAHP for selection of suitable projects in solar energy and wind power system	Used renewable energy resource for generate of electricity keeping healthy environment with rational cost in China is an important issue.	Identify the critical success factors for solar-wind generation system by using fuzzy AHP.	Results of this study demonstrated that; BOCR model can successfully and quite lever of complex problems with outstanding results.
[79]	Republic of Korea	Asia	FAHP and DEA	4	Used FAHP and DEA for allocation of R&D resources for efficiently energy.	Need to create long time strategic technology energy plan to enhance Korean national energy security and promote the "Low Carbon, Green Growth".	Presented the combine two-stage MCDM approach to assess the weights of five criteria to measuring the energy technologies efficiency against high oil prices.	Results of this paper found that; building envelope and energy conversion utilization had the best ranks simultaneously.

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Table 4 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[88]	United States	Northern America	AHP	6	Ranked technologies of electric energy production by used AHP.	Development of framework for decision makers is important issue to ranking numerous non-renewable and renewable electricity production technologies.	Used MCDM approach for measure and ranking of these technologies based on 4 important criteria including environmental, financial, socio-economic and technical.	Findings of this paper proved that, geothermal, solar, wind and hydropower has the significant rank and in case of non-renewable energy only 3 of 20 high rank positions were oil and gas.
[89]	Malaysia	Asia	IF-AHP	10	Applied IF-AHP for selection the best technology energy consumption.	There is crisis about global energy due to increase demand of energy in developing countries.	Proposed a novel approach based on MCDM techniques for choosing the best energy conservation and energy technology by evaluation of quantitative and qualitative criteria.	Outcomes of this paper found that, among seven alternatives the best alternative was nuclear energy in energy planning.
[80]	Greece	European union	ELECTRE III, IV, PROMETHEE I, II	5	Integrated ELECTRE III, ELECTRE IV, PROMETHEE I and PROMETHEE II for a wind-hydro hybrid energy evaluation.	There are some limitations for providing the appropriate power to human societies with other economic, resource, environmental techno-logical and social simultaneously.	Suggested the new MCDA-RES for hydro hybrid energy project with different criteria.	Findings of this study found that, MCDA-RES software can help decision makers for attain a compromise solution.
[90]	Taiwan	Asia	DEMATEL and ANP	6	Applied DEMATEL and ANP for carbon reduction management.	Need to develop strategy for reduction of carbon and evaluation of system.	Proposed a new approach for management of carbon reduction.	Findings of this paper found that, carbon risk assessment is the best criterion in the carbon reduction management system.
[91]	Greece	European union	New MCDM	14	evaluation of environmental supply chain performance by employed MCDM	In supply chain management environmental criteria are important which should include.	Proposed a novel model for evaluation of environmental performance criteria.	Findings of this paper indicated that, the proposed approach can use in businesses related to internal reporting which diverse alternatives.
[92]	China	Asia	AHP and fuzzy extent analysis	18	Evaluated performance by used AHP, membership degree analysis and fuzzy extent analysis.	Increasing of urban energy consumption lead to environmental problems due rapid economic development.	Proposed new method for evaluation of environmental performance by using MCDM techniques based on four different indicators.	Results of this study demonstrated that, the best scenario for energy use planning technology-led.
[93]	Poland	European union	AHP	4	Evaluated of operational performance by AHP in OSH management system.	Need to improve working conditions based on better prevention of occupational diseases.	Used the MCDM method for measurement of operational performance in the selection of leading key performance indicators.	Findings of this study indicated that AHP technique in suitable technique for selection of KPIs based on SMART criteria.
[94]	China	Asia	AHP	3	Used AHP for evaluation of combined heating, cooling and power systems.	Need to propose a new measurement for using energy by CCHP system rationally in Japanese buildings.	For comprehensive evaluation of CCHP system, this study used simple assessment from energy, MCDM technique and environmental and economic aspects.	Results of this paper proved that, hospitals and hotels have better performance than other offices and stores.
[95]	Serbia	Europe	VIKOR	6	Employed VIKOR for residential building refurbishment.	Need to comprehensive method for solar water heating systems (SWHSS) integration due to complexity of this system based on its criteria.	Recommended a new MCDM method for selecting of the best SWHS integration.	Findings of this paper found the systematic and clear way for achieve the optimal design solution for SWHS integration related to criteria and preference structure.
[96]	Iran	Middle East	SWARA and COPRAS	11	Implemented of SWARA and COPRAS for development of building structures	Nowadays sustainable development in rural areas in important issue.	Investigated of sustainable development in rural areas based on MCDM techniques in the building structures.	Results of this study found that stability is the best criteria for improve of the sustainable development in rural areas.
[5]	USA	Northern America	MCDM	9	Utilized MCDM for confidence of Building public in energy planning systems	Need to build understanding of people related to MCDM approaches.		Outcomes of this paper demonstrated that confidence building and learning is the best criteria for using different MCDM approaches.

distribution results of decision making approaches. Results of this table found that 21 papers employed fuzzy MCDM and MCDM approaches in the area of energy management. Findings from this table showed that of 21 published papers, majority of the studies were using AHP and fuzzy AHP mixed with other tools, followed by ELECTRE with other techniques. In addition, the findings shown in this table revealed that one paper was published in 2015, five papers in 2014, and four papers in 2013.

#### 4.2.3. Distribution of selected papers based on waste management

The best selection of waste process technologies and efficient waste management strategies offer opportunities to minimize the environmental impact, particularly through energy and materials recovery [97]. An effective waste management strategy must account for the complex interdependencies and interactions among waste handling processes and their effects on competing management objectives (e.g., minimizing cost, maximizing net energy production, increasing waste diversion from landfills, and minimizing GHG emissions). Results of Table 5 found that 16 papers employed fuzzy MCDM and MCDM approaches in area of waste management. The table shows that the most applied techniques are AHP and fuzzy AHP mixed with other tools, and TOPSIS and fuzzy TOPSIS with other techniques. In addition, the results in this table show that in 2015 two papers were published and in 2014 were three papers and year of 2013 three papers were published.

#### 4.2.4. Distribution of papers based on sustainability assessment

For development of projects related to sustainability assessment in different countries need to integrate values of sustainable development with programs and policies. According to Ness et al. [114], sustainability assessment aims to evaluate global and local integrated nature–society systems from long and short term perspectives in order to help DMs recognize the actions that should or should not be taken to make society more sustainable. The sustainability assessment was defined by Devuyt et al. [115] as “a tool that can help decision-makers and policy-makers decide which actions they should or should not take in an attempt to make society more sustainable.” According to four dimensions of sustainability, a number of comprehensive frameworks have been proposed for integrated assessment [116]. In 1996 a group of researchers provided a set of useful guidelines in the form of overarching principles to link practice and theory for the assessment process, including identification of indicators and system design, field measurements and compilation, and the communication and interpretation of results [117]. During the past decade, several concepts have been developed, which have been aimed to upgrade the operationalization of the sustainability vision. This resulted in various approaches claiming that they could be applied to the assessment of sustainability in a variety of sectors— e.g., jet biofuels [118], energy projects, building assessment [119], electricity systems [120], hydro-power projects [121], residential buildings, forest energy, agro-ecosystems [122], PV solar power [123]. Findings of Table 6 indicate that 18 papers employed fuzzy MCDM and MCDM approaches in area of sustainability assessment. Results of this table show that of 18 published studies, AHP and fuzzy AHP mixed with other tools were employed the most. Furthermore, the results in this table show that in 2015, four papers, in 2014, and in 2013 five papers were published.

#### 4.2.5. Distribution of papers based on renewable energy

Renewable energy is important in terms of strengthening the local improvements. Renewable energy is environmentally friendly, available abundantly and can be widely distributed. Renewable energy development has direct impact on increase of employment, stimulates economic growth and technological progress. In this way, renewable energy resources are an essential ingredient in doing business responsibly and successfully. That is why there is a growing interest in renewable energy both in the developed and developing countries.

Though, there are several problems facing [142,143] the activities to increase use of renewable energy, that should be understood and correctly interpreted into an inclusive controlling framework. The initial and notable problem for greater renewable penetration into energy organizations refers to the high-up front charges and associated inadequate cost usefulness. There are several market barriers and failures preventing penetration of renewables, such as commercialization barriers faced by new technologies competing with mature technologies; price distortions from existing subsidies and unequal tax burdens between renewables and other energy sources; failure of the market to value the public benefits of renewables and other, such market barriers such as inadequate information, lack of access to capital, “split incentives” between building owners and tenants, and high transaction costs for making small purchases etc. Consequently, it is significant to present financial support mechanism and satisfactory advancement arrangements, particularly ones which will interest isolated funding into energy segment and in such way decrease the monetary load on the public budget [144,145]. An MCDM process can be used as part of a pre-feasibility study to prioritize renewable energy projects [146]. There are various tools currently being used to facilitate decision making [147,148] selecting renewable energy projects. The tools are mainly used to help the decision makers reach consensus in terms of prioritizing the necessary renewable energy projects through an objective ranking procedure. Data are needed to formulate a viable group decision. Table 7 shows that, 11 papers employed fuzzy MCDM and MCDM approaches. The table indicates that commonly used techniques are AHP and fuzzy AHP mixed with other tools, followed by PROMETHEE and TOPSIS. Furthermore, the results in this table show that three papers were published in 2015, one paper in 2014, and two papers in 2013.

#### 4.2.6. Distribution of papers based on energy sustainability

According to Skoulou, Mariolis [159], the latest developments in energy policy have reflected a tendency for increasing the energy manufacture portion out of the recyclable energy resources, not merely about tactical reasons, but likewise for socio-economic and environmental aims. Some previous studies such as Balezentiene, Streimikiene [160] believed that production of biomass can improve for agricultural business due to diversification opportunities. As a result, several studies offered new visions about a recyclable energy strategy from the agricultural perspective. For instance, in the Czech Republic, Havlíčková and Suchý [161] analyzed the energy based on future prospects. employ data envelopment analysis (DEA), Ātkov and Effenberger [162] analyzed the effectiveness of biogas plants, while Madlener, Antunes [163] additionally made use of MCDM approaches about the final goal. Problems regarding energy development are complicated, with several DMs and several principles. Therefore, these difficulties are appropriate to the MCDM application. Findings from Table 8 show that nine papers employed fuzzy MCDM and MCDM approaches in the area of energy sustainability. Results of this table indicate that AHP and fuzzy AHP mixed with other tools, PROMETHEE and MULTIMOORA were the most employed techniques in this research area. Furthermore, the results in this table show that in 2015, one paper, in 2014, one paper, and in 2013, three papers were published.

#### 4.2.7. Distribution of papers based on land management

Modern planning theories inspire methods which reflect all investors and their diversity of discourse standards for avoiding political as well as scheming judgements [171]. During the current previous ten years, using the quantitative methods like the multi-criteria decision making methods in land suitability processes was improved, that permits using the varied information. Most of these activities chiefly applied decision-making methods for ranking the significance of predefined organization choices or planning developments. Table 9 illustrates that eight papers employed fuzzy MCDM and MCDM

**Table 5**  
Distributed papers based on waste management.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[98]	Croatia	Europe	PROMETHEE	3	Employed PROMETHEE for identify solid waste management criteria.	There serious problem regarding to inadequate waste management and waste production in some part of coastal of Croatia.	Suggested a novel integrated model based of two MCDM approaches by evaluating of some criteria such as social, ecological, functional and economic.	Results of this paper indicated that, this proposed approach presented a new perspective to planning of waste management in the strategic level and rethinking about some strategic waste management in this country.
[99]	Italy	European union	AHP	3	Used AHP for comparison of different waste management solutions	There are some problems in Saharawi comps related to bad conditions for living people and food consumption which comes from humanitarian help reasons the generation of several solid wastes which can impact of environment and health risks.	Applied of decision making approach for comparison of diverse waste management solutions in Saharawi refugee camps.	Findings of this paper found that two proposed solutions had the best scenarios regarding to waste management. In addition; it is very important aspects in an environmental and humanitarian project.
[100]	United Kingdom	European union	MCDA	6	Applied MCDA for evaluation of waste management.	Need to manage some options the waste paper on the Isle of Wight.	Recommended the MCDA approach by using panel of stakeholders and local residents for evaluation of the options for manage waste paper.	Results of this paper indicated that; recycling and gasification achieved the first rank in the manage waste paper.
[101]	Turkey	Europe	MCDA	3	Selection of site selection for the disposal of municipal solid wastes which	There are some problems related to operations of waste management for the disposal of municipal solid wastes (MSW).	Proposed MCDA technique for criticize the important selection site for disposal of MSW.	Findings of this paper found that; the novel structure with some main criteria can effective for solution of the waste management operations.
[102]	China	Asia	OWA and F-VIKOR	4	Used OWA and F-VIKOR for evaluation of health-care waste disposal	There is a challenge in developing countries related to selection of suitable treatment approach in HCW management.	For solving this challenge authors of this paper proposed a new MCDM approach for HCW disposal.	Finding of this paper indicated that; steam sterilization was the best technology of HCW treatment.
[103]	Canada	Northern America	MCDA	5	Review on municipal solid waste management.	Need to review of MCDA approaches which solving MSWM problems and most related multiple stakeholders.	Reviewed all published papers related to multiple stakeholders and MSWM problems by application of MCDA approaches.	Finding of this review found most important participant of published reviewed paper were municipalities/government and AHP technique is popular approach in Results of this study show that AHP has the first rank for implementation of multiple stakeholders.
[104]	Spain	European union	PROMETHEE, AHP	6	Employed PROMETHEE, AHP for municipal solid waste treatment ranking	There is problem in the selection of MSW treatment due to exist of various criteria such as environmental, social and economic.	Highlighted the most important indicators related to environment and sustainability for providing the comprehensive evaluation.	Finding of this paper found that; The ranking obtained in both cases was (from best to worst): thermal plasma gasification is the best criteria related to MSW treatment.
[105]	China	Asia	AHP and TOPSIS	3	Used AHP and TOPSIS for evaluation of waste management systems.	There is challenge in making decision on selection of environmental friendly, energy efficient and economically affordable of MSW management.	Used the life cycle assessment (LCA) for MSW management with attention to the economic factors.	Finding of this paper found that; that incineration scores and performs is the significant scenario from other scenarios.
[106]	Serbia	Europe	AHP	7	Used AHP for assessment of waste management sustainability.	Need to consider all important criteria related to waste management sustainability scenario based on energy recovery.	For consideration of all criteria and sub-criteria of sustainability related to waste management this study used MCDM technique.	Results of this paper found that; recycling of inorganic waste and composting of organic had the best ranks in assessment of waste management sustainability.
[107]	Portugal	European union	AHP and IVF-TOPSIS	5	Employed AHP and IVF-TOPSIS for solid waste management assessment.	In recent there are some challenges about SWM in Europe for fulfillment of the organic waste recovery and prescribed targets of recycling.	This study to retrieve the societal ramifications proposed a new integrated method which called AHP-based IVF-TOPSIS method.	Outcomes of this paper demonstrated that, the proposed AMARSUL system can select the PAYT, handling of recycling and selection of the best option.
[108]	Canada	Northern America	SWA, TOPSIS and ELECTRE	12	Assessed solid waste management by utilized SWA, TOPSIS and ELECTRE	It is require to compromise between possible conflicting intangible and tangible criteria for selection of best location of landfill.	Integrated five MCDA techniques for selection the best alternatives of landfill for solving problem related to SWM.	Finding of this study indicated that, for selection of landfill problems related to WSM, need to apply some MCDA techniques, because, each technique has

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Table 5 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[109]	Lithuania	European union	ARAS-F and AHP	10	Employed ARAS-F and AHP for incineration of non-hazardous waste.	There is problem related to increasing of heat and electricity prices.	Proposed new integrated approach for minimize cost regarding to electric energy production.	different result. Results of this study proved that; the selected industrial equipment parts covered the three different perspectives including the social, economic and environmental.
[110]	Taiwan	Asia	DEMATEL and ANP	17	Employed DEMATEL and ANP for evaluation of solid waste management	There is a problem for evaluating and selecting of the MSW management which expert group can improve this issue.	Evaluating of MSW management, need to use robust MCDM approach which consider large number of criteria.	Findings of this paper found that, a resource recovery facility and thermal the most solutions regarding to MSW management.
[111]	Canada	Northern America	TOPSIS, SWA, WP and ELECTRE	7	Applied TOPSIS, SWA, WP and ELECTRE for evaluation of solid waste management.	Need to focus on design of SWM systems based on multi alternative solution and criteria evaluation due to conflicting and complex influence on different stakeholders.	MCDM approach proposed for solving this kind of problem in selection of landfill.	Results of this paper proved that, MCDA approaches create a methodical method for connecting to the SWM problem and results can generated to solve problem related to landfill selection.
[112]	Australia	Oceania	Fuzzy AHP	4	Selected natural wastewater treatment by utilized FAHP.	Few of previous papers focus on combining the several aspects of wastewater treatment including technical, management and ecological economic and environmental factors.	For combining of various aspects and selection of natural wastewater treatment, this study proposed new MCDM approach based on FAHP with MDS.	Finding of this paper found that, the best alternative among all natural wastewater treatment systems was stabilization pond.
[113]	Republic of Korea	Asia	WSM, fuzzy TOPSIS and TOPSIS	3	Evaluated treated wastewater locations by used WSM, fuzzy TOPSIS and TOPSIS	Need to present strategies framework for climate change adaptation	Proposed robust ranking framework to finding of TWW use locations with emphasize on several uncertainties inherent in process of decision making.	Results of this paper indicated that, the opportunity payoffs in DR are significantly higher regarding of the DMCU philosophies, proposing that DR is a robust alternative for usage of TWW.

**Table 6**  
Distributed papers based on sustainability assessment.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[124]	USA	Northern America	MCDA	8	Assessed PGIS for by applied MCDA for sustainability of offshore wind farm.	Need to implementation and design of web-based participatory GIS model for analysis of offshore wind suitability.	Established the implementation and design of conceptual model for asynchronous and distributed web-based PGIS.	Findings of this paper revealed that most important criteria was fish habitat and utilities and shore were the significant criteria in terms of distance for selection of location regarding to wind farm. Results of this study found that, community ideology and spontaneous participation of the residents are significant highlighted, and some factors such as of under the open space, safety requirement and green environment with public facilities should be in the community.
[125]	Taiwan	Asia	fuzzy Delphi method and ANP	13	Developed housing community sustainable evaluation by used FDM and ANP.	In sustainable development, it is necessary to changing of abstract concepts for implementation in the residential environment in global view.	For evaluation model related to sustainable development factors and regional sectors demands, this study suggested A MCDM integrated approach.	Results of this paper indicated that, the suggested MCA model was suitable very positively for process of decision in the public open space renovations.
[126]	Italy	European union	AHP	3	Used AHP for assessment of urban open space.	There is problem in open space which richness and heterogeneity is usually neglected and contribution of the community overlooked within existing planning instruments.	Presented and developed a decision making process for selection and evaluation of renovation scenario related to open space renovation.	Findings of this paper indicated that, the suggested MCA model was suitable very positively for process of decision in the public open space renovations.
[127]	India	Asia	FAHP and fuzzy multi-objective LP	4	Employed FAHP and fuzzy multi-objective LP for evaluation of performance.	Due to growing of business activities and primarily focus of SC on some economic activities need to measure and develop of supply chain sustainability.	Developing of sustainable SC performance measures and proposed a partner selection with flow allocation of DM approach.	Results of this study found that, study respondents measured the performance of sustainable production which should be the first significant and important in develop a sustainable SC in the apparel industry.
[128]	Trinidad and Tobago	The Caribbean	MAHP	57	Applied modified AHP for assessment of performance of Sustainable Life cycle.	Assessment of sustainable performance criteria is important issue in building envelope is technically complex and challenging.	Integrated IPM and Integrated Criteria Weighting model for determine the criteria weighs in evaluating of the sustainable performance and selection of sustainable envelope design.	Results of this paper found that: the proposed approach successfully help to solving problems related to building envelope sustainable performance for reach the building sustainability.
[129]	UK	European union	five MCDA tools	3	Review on sustainability assessment by applied five MCDA tools.	Need to management of sustainability assessments due to various information types and uncertainties.	Assessment of sustainability tools based on five MCDM approaches should be satisfied, among uncertainty and thresholds, life cycle perspective, ease of use and software support.	Findings of this study overall indicated that, some of the requirements can satisfy MCDM approaches by excluded of information types and modify of life cycle perspective which were supported by all mentioned approaches.
[130]	Italy	European union	AHP	3	Utilized AHP for sustainable plant design and production evaluation	Need to present an energy supply DSS framework for sustainable plant production and design.	Applied a novel mathematical method for eco-industrial park (EIP) background by proposed DSS framework.	Results of this paper found that, relevant variation in BAU ranking is needed proposing that the alternative ways were significantly more valuable than the BAU item.
[131]	Brazil	South America	AHP	3	Used AHP for sustainable water management assessment.	Water management related to mining is important issue for sustainability due to the robust dependence on this resource, particularly for the operations with beneficiation plants.	Proposed the stepwise process by combining the environmental risks in DM by employ a multi-criteria and AHP in this Brazil.	Findings of this study indicated that, this proposed robust technique is suitable for selection and assessment of case study alternative and can be employed by corporate decision contexts where environmental risks are relevant.
[132]	USA	Northern America	ELECTRE III	3	Analyzed sustainable EMS by used ELECTRE III.	Need to consider all social, economic and environmental criteria for active management related to some initiatives like sustainability, cleaner production and pollution prevention.	Suggested a strategic positioning of clean production and pollution prevention projects by sustainable environmental management system design which responsive to regulatory requirements and related to culture and structure of industry and business.	Results of this study demonstrated that, waste streams management in the energy drink of manufacture and diet bars for presented the sustainable environmental management system which can be implemented and designed.

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Table 6 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[133]	Turkey	Europe	FANP	4	Applied FANP for selection of sustainable supplier	There is problem for identify a effective framework based on principles of sustainability for operations of supplier selection in supply chains.	Proposed a novel framework by using MCDM technique under incomplete preference relations for sustainability evaluation process.	Finding of this paper proposed and analyzed of the suppliers sustainability in the real-life problem to determine the validity of the proposed evaluation framework.
[134]	France	European union	Choquet integral and ELECTRE	3	Employed Choquet integral and ELECTRE for implementing of sustainable development	Sustainable Development implementation in organizations is the difficult action due to deal with conflict and incommensurable aspects such as social, economic and environmental dimensions.	For manage of some problems related to sustainable development implementation this study proposed a MCDA methodology.	Finding of this study indicated that, implementing outranking model and of a mono-criterion synthesis method were done to respectively rank 22 SD strategic activities in expertise Institution and rank 20 practical operational activities to control energy consumption of the Institute's buildings.
[135]	Sweden	European union	MCDA	3	Sustainability assessment based on SCORE by used MCDA methods	Need to assessment of sustainability very transparent by considering most important criteria in the social, economic and environmental dimensions.	SCORE (Sustainable Choice Of Remediation) based on MCDA-method was proposed for assessment of sustainability.	Outcomes of proposed SCORE method used for kinds of remediation in some locations such as Austria and Sweden, rural and urban setting, pollutants types, some areas such as groundwater, soil, surface water and finally liability.
[136]	Portugal	European union	ELECTRE TRI	7	Applied ELECTRE TRI for environmental sustainability evaluation	There are some lacks in the GIS technology from various weaknesses due to huge section to the lack capable analytical capacity of spatial decision problems supporting.	Proposed a Web MC-SDSS operational model fully combing GIS system and a definite MCDA approach – ELECTRE TRI, by the creating of Macro written in VBA in ArcGIS software.	Findings of this paper found that MC-SDSS approach provided optimal decision support tools by presenting a view for the combining of the models, information and methods which require for evaluation of environmental sustainability in dairy farms.
[137]	Canada	Northern America	AHP	3	Employed for AHP sustainability assessment	Reusing of the manufacturing systems in developing countries is today concern.	Developed a novel MCDM approach for evaluation of reusing benefits in the manufacturing systems in developing countries in terms of three main sustainability criteria such social, economic and environmental dimensions.	Finding of this study found that, economic criteria of sustainability were the main focus in developing countries and environmental criteria was the last rank.
[138]	UK	European union	PROMETHEE	7	Applied PROMETHEE for assessment of forest management sustainability.	There is serious threat related to economic production and ecological systems due to continuous deterioration in Ethiopia.	To evaluated the problems of forest management this study applied the MCDA in Ethiopia	Findings of this study indicated that, need to awareness of local people related to sustainability, need to suitable holistic scheme for harmonization of economic and environmental criteria, MCA approach is the best tool for evaluating of sustainability criteria and need to select and assess criteria set for sustainability path.
[139]	Turkey	Europe	FMAUT	37	Applied FMAUT for measurement of sustainability performance.	Need to show the sustainable SC performance measurement in single one-dimensional.	Proposed a novel MCDM approach based on fuzzy Entropy and fuzzy MAUT to assessing and comparing the company performance regarding to sustainable SC.	Outcome of this paper indicated that, based on proposed model, 2007 year has the first regarding social, economic and environmental dimensions, while 2003, 2004 and 2003 has the worst rank in these regards.
[140]	Denmark	European union	fuzzy TOPSIS	4	Applied FTOPSIS for sustainability performance measurement.	There is lack in previous studies which did not consider sustainability issues in selection of suppliers.	Examined and assessing sustainable supply chain initiatives problems based on Triple Bottom Line (TBL) approach.	Finding of this paper help to companies in four different ways including: selection of the best supplier among other, working with supplier group continually, suggested certain suppliers for enhance some of their defects and

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Table 6 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[141]	Canada	Northern America	AHP	10	Applied AHP for assessment of Life cycle sustainability.	Need to assess and compare some materials related to sewer pipe materials based on sustainability criteria.	Proposed and used two kinds of life cycle sustainability assessment based on MCDM approaches.	stop working with some certain suppliers. Findings of this paper found that polyvinyl chloride (PVC) pipe is the best sustainable option from economic and environmental aspects.

approaches in area of land management. In the field of land management, findings of this table demonstrated that the most popular techniques used were AHP and fuzzy AHP mixed with other tools. Moreover, the results in this table show that one paper was published in 2015, one paper in 2014, and two papers in 2013.

4.2.8. Distribution of selected studies based on green management topics

In recent years, there has been an increasing awareness of environmentally conscious practices [179]. These practices include environmentally friendly design (sometimes referred to as eco-design), green procurement, sustainable operations, and a number of end-of-life practices such as recycling and remanufacturing. Environmental awareness may be a consequence of regulatory pressures to protect the environment. It should be noted that “green” values and schemes considered essential for businesses as communal consciousness was developed regarding their ecological influences [180]. With the increasing awareness of the importance of environmental protection, organizations are obliged to take into account environmental practices, both to boost their image of being a “green” company and to actually work to protect the environment [181]. In this regard, companies try to put more standards and obligations on activities such as raw material extraction and overflowing waste sites to prevent environmental deterioration and pollution as an increasingly important issue for a business [182]. Nowadays, identifying appropriate and green providers in the supply chain considered as an important strategic issue. Industrial production can cause damage and have an excessive influence on the sustainability of the natural environment and on humanoid lifecycle itself; those influences contain depletive supply usage, worldwide ecological effects, local ecological effects, well-being influences, and safety hazards. These types of recyclable subjects have obtained much focus during the recent years, and supply chain operations that consider sustainability have become a progressively significant theme. These increasing interests and the significance of the supply utility increased the significance of the ecological activities of providers [183]. Supplier identification is an MCDM problem including both quantitative and qualitative standards that, together, are in conflict. During the previous few years, several investigators were focused on selecting the supplier problem to improve appropriate decision-making approaches which might associated with the problem effectually [184]. Some recent works are shown in Table 10. The table indicates that 13 papers employed fuzzy MCDM and MCDM approaches. Results of this table illustrate that of 13 published studies, five papers used AHP and fuzzy AHP mixed with other tools, three papers used VIKOR and fuzzy VIKOR and five papers used fuzzy TOPSIS and TOPSIS. Moreover, the findings of this table show that; in 2015, four papers, in 2014, four papers, and in 2013, two papers were published.

4.2.9. Distribution of selected studies based on water resources management

Water resource management is an extraordinarily challenging realm in which consideration should be given to the complex behaviors of both the natural environment and human settlements. While the challenges are often grand, managing water resource systems is critical and high on the priority lists of various organizations (ranging from grass-roots groups to international agencies), although management contexts vary significantly by region or country. During the recent years, technical instruments to model water capitals difficulties, were developed meaningfully and MCDM processes are extensively deliberated to be highly practical in determining conflicts associated to water management. The practicality of these actions relies on the rational assembly of assessment processes and on the common scheme industrialized to define and discuss complicated water difficulties. Lastly, MCDM simply contains the consequence of doubts that frequently typifies water management difficulties in the decision-

**Table 7**  
Distributed papers based on renewable energy.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[149]	Taiwan	Asia	Multi-choice goal programming	7	Employed Multi-choice goal programming for selection the best location for facilities of renewable energy	Need to evaluate the planning of capacity expansion problem in the renewable energy industry based on ideal mix of location selection, different plant types and other criteria. Due to the complexity of energy projects and energy planning need to develop and proposed a new dynamic model for reaching group consensus in projects of renewable energy.	Proposed a novel approach is superior to the goal programming by Ramón and Cristóbal, in for avoid underestimation of aspiration level.	Outcomes of this study found that; these goals are attained: social acceptance of 42.87%, power generation of 197%, investment cost of 131.5% attained based on MCGP-U.
[147]	Greece	European union	PROMETHEE II	5	Assessed renewable energy projects by applied PROMETHEE II.	Due to several criteria for implementation of renewable energy projects a traditional single criterion cannot handling this implementation.	Developed a MCDM approach based on PROMETHEE II for evaluating and selecting of renewable energy projects.	Results of this paper indicated that, developed framework presented the user-friendly method, enhance synergy among many actors and can cover a wat towards consensus.
[150]	Romania	European union	VIKOR	7	Assessed renewable energy projects by used VIKOR.	Due to several criteria for implementation of renewable energy projects a traditional single criterion cannot handling this implementation.	For solving these kinds of problems for implementation of renewable energy projects need to consider all criteria, this study presented a VIKOR and AHP techniques for selection of a renewable energy project corresponding to the renewable energy Plan launched by the Spanish government.	Findings of this study indicated that biomass plan alternative is the best option follow by solar thermo-electric and wind power for implementation of renewable energy project.
[151]	Greece	European union	AHP and PROMETHEE	5	Selected of renewable energy by applied AHP and PROMETHEE.	Renewable Energy Sources (RES) is the important requirements for desalination process.	Evaluated five kinds of topologies regarding to energy generation of Reverse Osmosis desalination process by using AHP and PROMETHEE.	Findings of this paper found that; hybrid configuration and direct connection selection were optimum solutions.
[152]	Republic of Korea	Asia	FAHP	5	Applied FAHP for assessment renewable energy factors.	For using renewable energy resources in Korea need to program by consideration of new R & D and renewable energy technology	For evaluation of renewable energy resources need to select the important criteria and factors based on economic, technological, market-related, policy-related and environmental.	Results of this study found that; economic feasibility was highest weight among other factors: the second highest weight was power of domestic technology and global market size and competitiveness ranked third weight.
[153]	Iran	Middle East	AHP	5	Utilized AHP for selection of renewable technology portfolio.	Nowadays due to high level of competitiveness firms and organizations should allocate their resources for selection the best projects.	Developed a mathematics approach for selection of renewable technology portfolio in the R & D center of oil industry for increasing of value and strategy of organizations.	Results of this proposed model can decrease the time related to assessment the portfolio, this model can answer some question regarding changes or addition projects related to budget and finally, model can balances the portfolio based on organization objectives.
[154]	United Kingdom	European union	PROMETHEE	9	Assessed of energy renewable sustainability technologies by used PROMETHEE.	Need to present the best decision support tools for selection of most suitable and sustainable options for finding of locations related to renewable energy technologies.	Provided and used a MCA technique for sustainability assessment in the national level and rank eleven renewable energy technologies.	Findings of this paper indicated that, rank of provided through the MCA technique is greatly uncertain and that effectively any rank of the eleven renewable energy technologies is possible caused by the uncertainty in the used values of criteria.
[155]	Iran	Middle East	COPRAS and AHP	8	Employed COPRAS-AHP for selection renewable energy	Renewable energy is important issue in the world because environmental problems and limitation of other resources.	Selected, evaluate and ranking of renewable energy alternatives are multi actors and MCDM approach is powerful tools for this goal, therefore; this study integrated AHP and COPRAS for evaluation and ranking of renewable energy alternatives.	Findings of this study indicated that, effectiveness and capability of the integrated model in selection of the most suitable renewable energy item among other alternatives.
[156]	Turkey	Europe	TOPSIS and ANP	7	Evaluated renewable energy development by used TOPSIS and ANP.	Need to assess the native and renewable energy sources which improve sustainable development problems in Turkey.	For this reason, authors of this paper integrated MCDM approach for assessing of renewable energy sources based on social, environmental and economic	Results of this study found that, hydraulic had the first rank among other alternatives follow by, geothermal, solar, biomass and wind.

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Table 7 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[157]	Turkey	Europe	fuzzy AHP	14	Assessed renewable energy development by utilized fuzzy AHP.	There is challenge in Turkey energy consumption which increased dramatically.	Evaluated and ranking of renewable energy alternatives based on social, environmental and economic factors.	Findings of this paper found that; the most important renewable energy alternative in Turkey were wind, solar, geothermal and hydropower.
[158]	Greece	European union	TOPSIS	6	Assessed renewable energy development by applied TOPSIS.	For sustainable development we should see the renewable energy resources which decrease the carbon emissions, reduce fuel and fossil imports and see the other energy policy objectives.	Provided the flexible and transparent MCDM approach for assessment of renewable energy resources based on extension of TOPSIS and 2-tuple representation.	Finding of this study found that, a solar collector in the household sector is the best option of sustainable renewable energy resources.

making procedure [196]. There is considerable research about water resource planning and management using MCDM techniques. MCDM methods were used to the selection of difficulties in watershed management [197], collaborative environmental planning, land-use planning and optimal spatial distribution [198], strategies of land-use restraint, wastewater treatment alternatives, and groundwater participation, wastewater treatment technology, and water scarcity management [199]. Findings from Table 11 indicate that 10 papers used fuzzy MCDM and MCDM approaches. The table indicates that of 10 published studies, three papers used AHP and fuzzy AHP mixed with other tools, four papers used PROMETHEE. Furthermore, the results in this table show that two papers were published in 2015, one paper in 2014.

4.2.10. Distribution of selected studies based on climate change

Climate change is considered one of the primary environmental phenomena that has captured the world’s attention in recent decades [209]. Climate change has the potential to cause multiple negative impacts on human health and human life generally, especially in developing countries because of the difficulty of adapting and implementing public health programs [210]. Climate change may also cause changes in the manner and place that diseases develop and transform [211]. Mortality rates are expected to increase along with the increase in temperature, as more heat waves are expected in some parts of the world [212]. Regional water resources and water supply also will be greatly affected by climate change [213], as the demand for water is expected to become greater and water quality is expected to worsen. In short, climate change is likely to affect many water-related aspects of human well-being, from agricultural productivity and energy use to flood control, municipal and industrial water supply [213], water quality, and human health as it relates to water quality. The amount of water available for use will decrease as a result of climate change, through increased evaporative losses from bodies of water, reduced runoff, and increasing competition between different sectors [214]. Climate change has affected different species, populations, distributions, and interactions. Biodiversity is expected to be negatively impacted through reduced habitat suitability and reproduction performance [215]; indeed, some species are in danger of extinction because of climate change [215]. Recently, there has been a growing interest in climate change studies and other areas using MCDM approaches [216]. Table 12 illustrates distribution results of decision making approaches. Findings from this table indicate that 10 papers employed fuzzy MCDM and MCDM approaches in area of climate change. The table illustrates that of 10 published studies, four papers used AHP and fuzzy AHP mixed with other tools, four papers used ELECTRE and two papers PROMETHEE. Moreover, the results in this table presents that three papers were published in 2014, two papers in 2013.

4.2.11. Distribution of selected studies based on strategic environmental assessment

During the last 25 years, Strategic Environmental Assessment (SEA) has experienced a significant evolution. SEA extended the practice and concepts of projects’ EIA to focus likewise greater amounts of decision making. Some researchers [226] argued that there is a need for SEA to serve sustainability drivers, address the policy and organizational outline, and mix the social standards into the decision-making process. In addition, SEA should directly act on the preparation and improvement procedure of policies, plans, and programs (PPP) to enhance the volume of effective decision primacies and develop the ecological and sustainability incorporation into the decision-making procedure [227]. This evolution of SEA was associated with the development of multiple SEA interpretations, which was well documented by Silva et al. [228]. Table 13 indicates that seven papers employed MCDM and fuzzy MCDM approaches in area of strategic environmental assessment. Results of this table indicate that AHP and fuzzy AHP mixed with other tools were the most used techniques in this

**Table 8**  
Distributed papers based on energy sustainability.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[164]	USA	Northern America	MCA	9	Applied MCA for evaluation of sustainable bioenergy projects.	Main barrier for implementation of bioenergy projects in the resulting complexity constitutes.	Used MCDA to help the implementation and design of sustainable bioenergy projects.	Results of this paper indicated that, social criteria were identified by four kinds of MCDA tools as presence critical in making a bioelectricity project practical.
[165]	Greece	European union	PROMETHEE I and PROMETHEE II	8	Employed PROMETHEE I and PROMETHEE II for assessment of sustainable energy planning	Sometimes using of some traditional assessment approaches like, macro-economic indicators and cost-benefit analysis did not combine all environmental factors by energy plan.	Assessed planning of sustainable energy based on MCDM approach by consideration of economic, technological, social and environmental on the island of Crete in Greece.	Findings of this paper revealed that complexity of system based of multi-actor energy could be as an advantage in planning through using of MCA analysis to evaluate energy alternatives for sustainable planning.
[166]	Japan	Asia	AHP and PROMETHEE	4	Integrated of AHP and PROMETHEE for assessment of sustainable residential energy system.	Need to consideration of all economic, environmental and energetic effects on assessment of sustainable residential energy system.	Evaluated and design a model for using linear programming and MCDA evaluation method for define the optimal residential energy system through diverse types of information.	Results of evaluation model indicated that; nowadays renewable energy systems are not more competitive unless significant focus is should paid to some benefits such as environmental aspect.
[167]	Bosnia and Herzegovina	Europe	VIKOR	23	Assessed sustainable hydropower by applied VIKOR.	Numerous projects developed for minimize conflicts among Directives, sometimes presenting a criteria list for consideration when deciding on the influence minimization of new ones or warranty to existing plants.	Evaluated and selected 23 criteria related to environmental issue for by using VIKOR approach.	Results of proposed model indicated only 14 of criteria from 23 criteria of environmental aspect were convenient and applicable by most users.
[168]	UK	European union	MAVT	3	Assessed of sustainability in energy systems by used MAVT.	Needs to consider three sustainability dimensions including social, economic and environmental for sustainable development in energy system.	Integrated sustainability evaluation of energy system through MCDA techniques.	Findings of this paper found that, from 17 sustainability criteria using in this study the business-as-usual scenario, typically based on fossil fuels, is unsustainable regardless of the preferences for diverse sustainability criteria
[24]	Lithuania	European union	TOPSIS and MULTIMOORA	3	Used TOPSIS and MULTIMOORA for sustainable energy sources selection.	It is very important to present sustainable decision making for energy policy based on political, social, technological and economic, developments.	Applied MULTIMOORA and TOPSIS for selecting of the most technologies regarding to sustainable electricity production.	Results of analysis indicated that policy related to future energy must orient towards of technologies regarding the sustainable energy, namely solar thermal and water ones.
[160]	Lithuania	European union	Fuzzy MULTIMOORA	9	Assessed sustainable energy by applied Fuzzy MULTIMOORA.	Selection of sustainable energy crop should be include the environmental and strategic aspects which create biomass as important element and energy source in the sustainable energy policy which involve several uncertain data.	For ranking and selection of sustainable energy crop this study applied MULTIMOORA approach which enables to tackle imprecise information.	Results of this study various new crops for Boreal–Memoral region in Lithuania identified by using multiple environmentally compatible indices by the virtue of the multi-criteria ranking.
[169]	UK	European union	AHP, DELTAP and ROMETHEEII	6	Selected the suitable MCA method for sustainability energy systems.	Selecting an appropriate MCA approach for individual project is challenge reason by the complexity of participatory sustainable decision making in energy sector.	Provided a transferable method for selection of MCA for assessment of sustainability energy systems.	Findings of this study indicated that, MCA approaches and choosing the criteria found and summarized present a wide application potential to help MCA approach selection in the renewable and energy sectors.
[170]	Sweden	European union	MCA	12	Used MCA for assessment of energy sustainability technologies.	Increasing of energy prices, efficiency and energy demand are the most important issues in energy consumption.	Evaluated of Building Energy Performance Calculation Methodology (BEP-TR) by used fuzzy MCDM.	Findings of this study found that, the proposed model can help to decide which part will be the ranking criteria for enhance efficiency and effectiveness of their construction.

**Table 9**  
Distributed papers based on land management.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[172]	USA	Northern America	AHP and OWA	2	Evaluation the suitability by used AHP and OWA for selection of landfill site	There is lack in previous studies regarding to sustainability performance of energy technologies in the rural electrification.	Used Principal component analysis (PCA) for assessing sustainability performance based on energy technology sustainability index (ETSI).	Findings of this paper found that, some technologies such as biogas, biomass gasifiers and microhydro technologies has the better relationship with sustainability performance.
[173]	Iran	Middle East	AHP	3	Integration of landfill siting based on among economical environmental and socio-cultural expertise.	There is problem in selection of Landfill as important process of municipal planning which can influence in various regions regarding to different aspects such as environmental, ecological and economic the health sectors. Selection of landfill site is the complex multiple criteria land applies planning that must influence on all stakeholders with different perception. Need to comparison of presented ecosystem services in the landscape planning and land-use types.	For assessment of suitability of landfill site selection, this paper proposed GIS-based MCDA approach.	Outcomes of proposed model indicated that, the goal of this model was not to identify a single optimal solution, but to other strengths linked to weight flexibility of the OWA method.
[171]	Australia	Oceania	Fuzzy-AHP and AHP	23	Applied FAHP and AHP assessment of urban land-use planning	Selection of landfill site is the complex multiple criteria land applies planning that must influence on all stakeholders with different perception.	Integrated method for selection of landfill site based on different ideas among socio-cultural economic and environmental expertise.	Finding of this paper demonstrated that, the suggested crossing model can help to choose the most accurate landfill site.
[174]	Austria	European union	PROMETHEE	6	Analyzed landscape planning by applied PROMETHEE.	Need to comparison of presented ecosystem services in the landscape planning and land-use types.	Compared of land land-use types based on Ecosystem services criteria and using MCDA techniques.	Results of this paper indicated that, spruce forest had the first rank in the land-use alternative, traditional larch meadow had the second rank and intensive meadow was the third rank.
[175]	China	Asia	AHP	7	Applied AHP for Spatial analyzing system.	There is need to combing of an extensive kind of data on ecological and environmental process on urban development and planning in the urban land management.	For development of spatial analyzing system need to combined landscape ecological analysis, land suitability modeling with remote sensing (RS), and geographic information system (GIS) regarding to urban expansion land management.	Finding of this paper found that, reasonable land planning measures and land-use management policy should be modified to continue the sustainable development of Changsha City.
[176]	Brazil	South America	AHP	6	Applied AHP for ranking of environmentally valid highway restoration.	There is concern about Brazil condition paved highways which risky and investment limitation regarding of environmental and safety conversation.	For achieve ranking scores related to ranking of the environmental restoration in paved highway, this paper used FMCDM.	Results of this paper found that in two separate segments landslips and landslides and risk of erosion had the first rank.
[177]	Turkey	Europe	AHP	5	Utilized AHP for selection of solar farms site.	Due to using of solar energy and solar energy investments in Turkey, need to find appropriate site selection for solar energy farms.	Applied MCDM approach and GIS to finding the best area for solar energy farms in Turkey.	Findings of this study suggested that, the proposed methodology can help decision makers for solving problems related selection of solar farms site.
[178]	Iran	Middle East	ANP and DEMATEL	13	Applied ANP and DEMATEL for evaluation of Land suitability.	Site selection of wind energy as a resource of renewable energy is important issues in some countries due to some requirements such as careful planning and basic information.	This study for selection of suitable wind energy site in Iran, integrated MCDM approaches and GIS approach.	Finding of this study demonstrated that, east of the capital city was appropriate for wind energy site.

**Table 10**  
Distributed papers based on green management topics.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[185]	Malaysia	Asia	F-VIKOR	7	Used F-VIKOR for assessment of green supply chain practices.	There is problem to achieve the complete understanding related to green issues for consideration environmental regulations to companies and firms.	This study for solving this problem and evaluating of green SCM developed quantitative assessment for measurement uncertainty of green SCM by used fuzzy VIKOR approach.	Findings of this study found that; eco-design had the first rank among other criteria related to green SCM in Malaysian manufacturing mobile companies.
[186]	China	Asia	F-TOPSIS	9	Green supplier evaluation performance by employed F-TOPSIS	Green supply chain management, especially green supplier selection is a new and important issue for companies to attain the environmental sustainability.	For evaluation and selection of green suppliers this paper applied fuzzy MCDM.	Findings of this paper demonstrated that, such suppliers with the highest scores had the best environmental performance.
[187]	Hong Kong	Asia	AHP	14	Utilized AHP for assessment of Green construction for environmental management	There is lack in environmental tools evaluation related to construction industry.	This study proposed new system based on operational performance indicators and management performance indicators which called green 'green construction assessment for construction.	Results of this study found that, the proposed tool can help to evaluate contractor's performance and environmental achievements.
[188]	Iran	Middle East	COPRAS –G and ANP	6	Selection of greenhouse location by applied COPRAS–G and ANP	There is important problem related to greenhouse location selection due to several criteria and sub-criteria for analysis and assessment.	This study for selection of greenhouse location identified six factors and used COPRAS–G and ANP for assessment the greenhouse location based on these factors.	Results of this study found that, government, environment and physical condition were the best rank criteria in selection of greenhouse location.
[180]	Turkey	Europe	F-TOPSIS, F-DEMATEL and F-ANP	19	Applied F-TOPSIS, F-DEMATEL and F-ANP for evaluation of green suppliers	Nowadays finding the appropriate and suppliers in the key strategic in supply chain of companies due to environmental performance and image.	For selection of appropriate green suppliers this study investigated dimensions of green SC management and proposed a framework based on capability dimensions.	Results of this paper found that, the proposed framework evaluated the green supplier for improve of green SC management initiatives.
[189]	Denmark	European union	F-TOPSIS and F-AHP	5	Applied F-TOPSIS and F-AHP for evaluation of green suppliers	For selection of suppliers there are some problems related to quantitative and qualitative criteria due to limitations of suppliers.	For selecting, rating and evaluating of the best green suppliers, this paper used environmental and economic criteria based on fuzzy MAUT theory and multi-objective programming.	Results of this paper demonstrated that, proposed model can help to firms for creating of systematic model for undertaking of green supplier selection and problems related to order allocation in real case studies.
[190]	UK	European union	F-TOPSIS	22	Used F-TOPSIS for development of green product	There is problem to use traditional. Life cycle assessment (LCA) as popular method for measurement of environmental impact on development of new products.	For this purpose, this study modified the concept of Life cycle assessment (LCA) and presented a comprehensive approach which combine fuzzy TOPSIS and fuzzy extent analysis for environmental performance assessment with focus on diverse product designs.	Findings of this paper indicated that, packaging, transportation and life cycle phase has better performance regarding to environmental assessments.
[191]	India	Asia	fuzzy AHP	5	Used fuzzy AHP for analysis of risks in green supply chain	Identify of risks related to green supply chain are very important due to failure in the economic-ecological performance.	Identified and analysis of green supply chain which influence on implementation of green supply chain practices in industrial companies by using fuzzy MCDM approach.	Results of this paper found that, some risks related to operational category were the most important risks in green supply chain.
[192]	UK	European union	fuzzy AHP	25	Utilized FAHP for green design and life-cycle in the environmental management accounting	There is the major challenge in world competitive environment related environmental performance and costs in design and development phase of products.	Presented a comprehensive model for measurement of organizational and environmental performance by combine EMA and LCA and using fuzzy MCDM.	Results of this paper found that, Printed Circuit Board and Plastic were two important criteria in the product life-cycle.
[193]	Denmark	European union	fuzzy TOPSIS	17	Applied F-TOPSIS for selection of green suppliers	Nowadays companies faced with environmental pressure by stakeholders for using green practices in daily activities.	For selection of green supplier, this study proposed a framework based on green SCM practices and using fuzzy TOPSIS.	Findings of this study found that, four important criteria in selection of green supplier selection were; senior management commitment, product design for reduce toxic and energy, compliance with some regal environmental needs.
[194]	Turkey	Europe	VIKOR AHP, and fuzzy c-means	4	Applied VIKOR AHP, and fuzzy c-means for evaluation	Development of green supplier is the important activity for organizations for	For finding the supplier performance related to green and environmental, this	Results of this study indicated that, the proposed approach is very useful and (continued on next page)

Table 10 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[195]	Taiwan	Asia	F-ANP	4	of green suppliers  Applied F-ANP for evaluation of green suppliers	focus on environmental SC capabilities.  Need to a study for compare of close-loop and open structure and of green SCM in two different perspectives including: suppliers-manufacturer-customers.	paper performed a survey and factor analysis and for evaluation of factors and used fuzzy MCDM for evaluating of green suppliers. For investigation and comparison of these two models this study, considered criteria and aspects related to qualitative preferences of green SCM with using of fuzzy MCDM.	effective for supplier evaluation and segmentation problems.  Results of this paper concluded that; The structure of close-loop hierarchical very close with existing applications.

area of research. Furthermore, the results in this table show that one paper was published in 2015, and two papers in 2014.

4.2.12. Distribution of papers based on construction and environmental management

The negative impact of building and building operations on human health and the natural environment has been a subject of research interest in recent years [236]. The impact of the building industry on natural resources has shown direct and indirect relations between the construction industry and sustainable development [237]. The environmental impacts of the construction industry, such as resource depletion, biological diversity losses, poor indoor air quality, energy consumption, and emissions causing global warming, acid rain, and smog accounted for 40% and 16% of annual energy and water consumption worldwide respectively [238]. Due to the significant amount of energy consumption, the building industry had several environmental concerns, one of which is harmful emissions [239]. Sustainability literature has focused on defining and assessing environmental performance indicators and environmental scoring systems. Environmentally conscious construction has been studied, and a significant body of knowledge on environmental performance [240] methods of environmental impact analysis [241] and environmentally conscious construction management (e.g., [242]) has been demonstrated in literature. Environmentally conscious construction is defined as the encouragement of ecological, economic, and social-cultural sustainability in buildings [243]. Therefore, the concept includes environmental parameters, as well as other objectives. Although previous researchers have clearly summarized the significance of environmental impacts during the construction phase (e.g., [244]), there are still gaps between the ultimate goal of environmentally conscious construction and contributions of those studies. This is mainly because the purpose of most of the studies has been to solely understand and analysis the relation between environmental impact and construction processes, and they have overlooked the multi-objective nature of construction projects. Findings from Table 14 indicate that 21 papers employed fuzzy MCDM and MCDM approaches in area of construction and environmental management. Findings of this table show that of 21 published studies, the commonly used techniques were AHP and fuzzy AHP mixed with other tools, TOPSIS and fuzzy TOPSIS integrated with other tools and COPRAS. In addition, the results in this table show that one paper was published in 2015, four papers in 2014 and five articles in 2013.

4.2.13. Distribution of papers based on other energy management areas

Table 15 shows valuable distribution results of MCDM approaches based on authors, techniques and applications, year of publication, summary of papers, and criteria. Findings from this table indicate that 22 papers employed fuzzy MCDM and MCDM approaches in other areas of energy management, for example, [266] applied AHP and GIS for spatial data analysis, Malekmohammadi and Rahimi Blouchi [267] implemented of AHP for evaluation of ecological risk factors, Theißen and Spinler [268] used ANP for assessment of CO2 management reduction, Shaw, Shankar [269] employed FAHP and fuzzy multi-objective LP for low carbon development, Vadrevu, Eaturu [270] evaluated of fire risk based on FAHP and Lee and Chan [271] assessed proposals based on urban renewal by used AHP. Results of Table 15 indicate that bulk of the studies employed AHP and fuzzy AHP mixed with other tools. Furthermore, the results in this table show that two papers were published in 2015, four papers in 2014 and three articles in 2013.

4.3. Distribution of selected papers based on name of journal

Table 16 presents the journals distribution which was used in this paper. In total, 72 journals database related to the energy management

**Table 11**  
Distributed papers based on water resources management.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[34]	Spain	European union	AHP	23	Used AHP for strategic environmental assessment (SEA) for water programs.	Need to use SEA process for involving of social, economic and environmental aspects and combine with design planning and human development strategies in order to in order to encourage poverty reduction related to environment and natural resources.	This study used AHP approach for evaluation of water programs based on SEA procedure in developing countries.	Results of this study found that, AHP can help to SEA by finding the most suitable indicators for the control the influence of project.
[200]	Australia	Oceania	WSM and PROMETHEE	10	Used WSM and PROMETHEE for water resource analysis.	For selection of water supply source, there is need to consideration of sustainability criteria, such as social, environmental and economic criteria.	For select and evaluate the best source of water supply, this study used MCDA technique.	Results of this study found that, all approaches which used for criteria weights (CWs) were in appropriate agreement with regarding to which rankings can affected.
[201]	Australia	Oceania	PROMETHEE II and Evamix	98	Assessment of water resource management by utilized PROMETHEE II and Evamix.	Need to comparison of MCA approaches for evaluation of water resource management decision problems.	For this purpose, the author of this paper used five MCA techniques for six important more focus required on primary structuring of problems related to decision making which including selecting of the criteria and decision options.	Findings of this paper indicated that; although the choose of MCA approach is important more focus required on primary structuring of problems related to decision making which including selecting of the criteria and decision options.
[202]	Australia	Oceania	PROMETHEE	8	Evaluated of water supply system by applied PROMETHEE.	Evaluation systems of urban water supply with integrated of multi-objectives is efficiently done by using MCA techniques, when modeling and preference elicitation play as main role.	For evaluating of urban water supply systems this study explain the modeling process and preference elicitation by using PROMETHEE.	Findings of this study indicated that, the modeling preference factors can evaluate and compare of options operating roles when values of performance measure are available for individual operating rule.
[203]	Switzerland	Europe	MCDA/MAUT	27	Presented MCDA/MAUT for water supply planning.	Need to examine the for sustainable water infrastructure planning for undertaking uncertainty and predictive modeling for supporting of MCDM and MAUT.	This study used global sensitivity analysis (GSA) to evaluate of sustainable water infrastructure planning in a case study in Switzerland with comparison of 11 water supply alternatives.	Results of this paper indicated that, outcome uncertainty could be considerably decrease by additional elicitation of few parameters, for example the aggregation functions at higher-level nodes and overall risk attitude.
[204]	Lithuania	European union	AHP and ARAS-F	12	Applied AHP and ARAS-F for deep-water port selection.	Deep-water sea port has the important role in the model economy development; there is need to develop it for economic requirements satisfaction specially, Baltic see which is corridor between Western and Eastern Europe.	For cover and achieve these economy development, this study used MCDM techniques including AHP and ARAS fuzzy.	Findings of this paper demonstrated that; the proposed model appropriate for solving problems regarding to locations selection.
[205]	Iran	Middle East	SFOWA, ELECTRE I and MAUT	11	Presented SFOWA for assessment of water resources management with comparison of ELECTRE I MAUT.	There are various types of uncertainty related to water resources management and MCDM techniques.	For solving these kinds of problems related to MCDM, this study proposed new approach by integrating of fuzzy approaches and merging the stochastic and into the OWA operator.	Results of this study found that, with comparison of five methods, proposed model is the best method for solving this kind of problem.
[206]	USA	Northern America	A-IFS MADM	7	Proposed A-IFS MADM approach for selection of the best practices of Agricultural Management.	Need to best management practices for influence of ground water in agricultural practices.	This study for selecting and ranking the best management practices introduced new approach based on MCDM and Atanassov's Intuitionistic Fuzzy Set (A-IFS).	Findings of this study proved that; standardization of measurement model, particularly finding of reliable cheaper and methods would growth the usage of this best management practices (BMPs).
[207]	Iran	Middle East	fuzzy AHP	26	Assessed environment and water management by applied FAHP.	There is need to emphasis of environmental concerns related to water resources protection.	This study found effective external and internal factors and ranked sustainable development criteria by using FAHP and SWOT model.	Results of this study found that, "promoting stakeholders' participation" and "human resources management" were the best strategies.
[208]	USA	Northern America	PROMETHEE V	18	Used PROMETHEE V for assessment of Water resources planning	There is challenge in the middle east related to water resources issues due to the socio-political problems.	For assess and choose the water resources development options this study applied the PROMETHEE V technique.	Results of this paper found that, focus on conservation and domestic water supply rank measures and efficiency improvement were the best options.

**Table 12**  
Distributed papers based on climate change.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[217]	USA	Northern America	ELECTRE I, fuzzy sets and AHP	4	Used ELECTRE I, fuzzy sets and AHP for evaluation of climate change	Need to integrated assessment for evaluation of long-time plan about energy and environmental policy for climate change and greenhouse gas emissions.	For design and implementation of integrated assessment this study investigates the possible role of MCDM techniques.	Findings of this paper demonstrated that, MCDM techniques can integrate formal approach with data which traditional approaches may ignored such as preferences and users' background knowledge.
[218]	Greece	European union	AHP, MAUT and SMART	3	Evaluated climate change policy by integrated AHP, MAUT and SMART	Need to optimal techniques to help the government in order to finding and enhancing instruments related to climate change mitigation policy.	For evaluation of climate change this study integrated three MCA techniques including, AHP, MAUT and SMART.	Results of this paper demonstrated that, EU member state ready for implementation new measure related to climate policy, in addition; results found that plan has integrate the performances of seven countries are less than the half of the highest performance.
[219]	Lithuania	European union	MULTIMOORA	3	Employed MULTIMOORA for mitigation of climate change.	Need to look at harmony of climate change policies for rank of climate change mitigation based on influence of developments of sustainable energy goals.	For finding this goal this study, analysis EU climate change mitigation policies and energy, determine targets based sustainable energy development targets, suggested new techniques for assessment of climate change policies and finally ranking these policies in Lithuania.	Results of this study indicated that, the best policy related to climate change mitigation in Lithuania is include scheme of green certificate trading and scheme of EU GHG emission trading with higher than existing CO2 price.
[220]	Spain	European union	TOPSIS and AHP	4	Used TOPSIS and AHP for assessment of solar farms locations.	Need to optimal assessment for finding the best place for photovoltaic solar power plants in Spain.	For assessment and identify of best place for photovoltaic solar power plants, this study integrated GIS and MCDM technique.	Results of this study found that, based on location, terrain, climate and environmental characteristics the optimal place for install solar photovoltaic plants was Cartagena.
[221]	Greece	European union	ELECTRE III and PROMETHEE	10	Evaluated species in urban environments by employed ELECTRE III and PROMETHEE.	For enhance of urban climate trees can effect on various dimension and aspects, particularly in order to densely populated environments factors by high levels of air pollution.	For improve of urban climate and evaluate of performance index by pooling trees species, this study proposed a MCDM approach based on ELECTRE III and PROMETHEE	Findings of this paper indicated that, the high ranking of trees species in center point were C.australis M.Alba, styraciflua, Liquidambar and S.japonica.
[216]	USA	Northern America	AHP and fuzzy ELECTRE	6	Used AHP and fuzzy ELECTRE for evaluation of climate policy.	Assessment of policies related to preventing global warming require consider the uncertainties and multiple criteria.	For evaluation of climate change policy, this study combined the integrated assessment into MCDM techniques.	Findings of this paper indicated that MCDM techniques can contribute to climate changes policies in order to finding how policy selection can influence by disagreement for individual policies.
[222]	Iran	Middle East	fuzzy DEA	3	Employed FDEA for optimization of location for wind power generation.	Due to rapidly increase of wind energy demands around the world, need to focus on selection of best locations for wind power plants by consider of various local and social criteria.	For selection and evaluation of optimal location of wind plan this study integrated fuzzy DEA, Numerical Taxonomy (NT) and Principal Component Analysis (PCA).	Results of this study demonstrated that, consumers' proximity is the best factor in establishment of wind plant generation.
[223]	China	Asia	ELECTRE-II	5	Used for selection of macro site station of wind, solar and hybrid power.	Nowadays, there are several of lacks in implementing of solar and wind power generation systems such as site location selection, so, how to choose wind and solar hybrid station is the first problem in this regard.	This study presented a framework based on literature and some standard and experts opinions for selection of seven solar and wind hybrid stations by using of MCDM technique.	Results of this study found that, three important stations for implementing of this hybrid generation systems were, Erlian haote, Zhangjiakou and Yumen.
[224]	Taiwan	Asia	FANP	4	Applied FANP and ISM for analyzed PV solar cell.	Due to environmental protection and natural resource scarcity, using renewable energy resources such as solar cell, attempted to provide plentiful and clean energy.	This paper for develop of PV silicone solar cell power proposed a conceptual framework by fuzzy ANP with consideration cost, risks, opportunities and benefits for help to better analysis of	Outcomes of this study found that, family products, with emerging new parts and multiple product with updating of existing equipment were the best options for development of PV silicone

(continued on next page)

Table 12 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[225]	Italy	European union	PROMETHEE	7	Assessed of technologies in concentrated solar thermal by utilized PROMETHEE,	There are uncertainties about solar thermal technologies (CSP) due to lack of some information such as performance and cost and their influence on the environment of the system for primary commercialization in the market.	strategic products. This paper for evaluation of CSP technologies used some MCDM techniques such PROMETHEE.	solar cell power. Results of this study found that some alternatives using hybrid solar technologies with were the best alternatives than other alternative for assessment of CSP technologies.

and MCDM approaches and indexed in “Web of Science” were included on this review paper. In this regard; the first rank of scholarly journal was the journal of *Renewable and Sustainable Energy Reviews*, with 32 papers which contributed paper as the most significant journal related to the energy management and MCDM approaches. *Journals of Cleaner Production* and *waste management* had the second and third ranks with 13 and 10 papers respectively. In other journal rankings, *Journal of Energy Policy* with 9 papers had fourth rank, *European Journal of Operational Research* had the fifth rank with eight publications; finally, *Ecological Indicators*, *Expert Systems with Applications* and *Environmental Modeling & Software*, each with seven studies, had sixth rank. Table 16 has shown the frequency of other published scholarly journals.

4.4. Distribution of selected papers based on year of publication

In this section we presented the some significant information about the frequently of the publication years. Results of this distribution represented in Fig. 2. The outcomes of this table demonstrated that; duration of 1995 until 2015 using decision making techniques in energy management field increased dramatically. In addition; findings of this table found that, previous scholars only published one paper in 1995, although, numbers of publication has increased to four papers in 2005. Moreover; results of this section proved that; the numbers of published papers in 2014 and 2015 were 38 and 23 respectively. According to this finding and results, we can indicate that; currently scholars in different areas of energy management use the decision making techniques and we can predict these number of publications will increase.

4.5. Distribution of papers based on nationality of authors

Several of authors from different countries have involved in our review paper. According to Table 17, in total; 40 countries or nationality employed decision making techniques in various fields of energy management. Results of this table found that, Turkey with 7.61% was the first country from other countries. In this regards some countries such as China, United States and Greece had the second, third and fourth ranks with 14, 14, and 13 papers respectively.

4.6. Distribution of papers based on region area

Distribution of published papers based on region area is an interesting topic in our review paper. In this section, based on geography classification we showed that, which region used decision making approaches in fields of energy management.

According to our classification, in total; nine regions such as; Europe, Northern America, Asia, Oceania, European Union, Middle East, The Caribbean, South America were involved in our review papers, frequently of this classification provided in Fig. 3.

5. Discussion

This study contributes to literature by representing the possibility of integrating of energy management fields and decision making and in the procedure of MCDM approaches. The potential for finding the most feasible MCDM method under the influence of changing energy management systems conditions is promising. These complexities in generating the desired energy management decisions may be exacerbated by uncertainties existing in the related system components. For many decades, energy management problems, which have been accompanied by rapid economic and social developments, have been of great importance for both local and national governments worldwide. Recognition of decision schemes, with sound socio-economic and environmental efficiencies, is necessary for promoting effectual practices in energy management. Still, energy management systems are

**Table 13**  
Distributed papers based on strategic environmental assessment.

Author	Nationality	Region	Technique	Number of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[229]	Germany	European union	MAVT	22	Used MAVT for assessment of strategies in the nuclear remediation management	There are some differences on environmental emergency in various ways such as; their cause and their impacts of dimensions, so need to effective and coherent emergency management.	This paper used decision support tools for radiological accident or nuclear energy in Europe by applied MCDA techniques.	Results of this study found that; removal had the best rank follow by disposal, in addition; While acceptance had the huge contribution on overall performance and finally, impact was the best factor in differentiating of them.
[230]	Austria	European union	AHP and ANP	43	Comprised AHP and ANP for strategic management options.	Nowadays, sustainable forest management (SFM) is the one important topic in environment and forest policy which it is related to environment and forest policy.	Compared two different MCDM approached for assessment of sustainable management strategies at level of forest management for employ criteria and indicator method.	Findings of this study found that, combine data for interdependencies among sustainable forest management (SFM) system can lead to further comprehensive and transparent decision making in levels of tactical-planning and strategic of forest management.
[231]	Australia	Oceania	ELECTRE-SS	4	Applied ELECTRE-SS for selection of management strategy.	There is need to choose of a management strategy for the bio-degradable action in the MSW.	Proposed a novel process based on ELECTRE III by define of the pre-order and present a ranking index (RI).	Findings of this paper found that; anaerobic digestion and paper composting were less environmentally sound options than recycling.
[232]	Netherlands	European union	Fuzzy AHP	16	Applied FAHP for selection of PV technology.	Some technologies photovoltaic are available commercially, but some of them are not clear and which of these technologies will improve the main design.	Determined and analysis the most important technologies photovoltaic factors by using fuzzy MCDM technique.	Outcomes of this study found that, standard support strategy is the most important category, and two factors including technological superiority and pricing strategy were the most effective in the dominance process. chance of achieving dominance (30% chance).
[233]	USA	Northern America	AHP	4	Selected of strategy for reduction of CO2 by used AHP.	Need to some mitigation strategies for decrease carbon dioxide emissions for on-road transportation.	Analyzed and rank of several strategies related to on-road emissions mitigation such as replace strategies, avoid and reduce.	Results of this study found that; reduce strategies were the highest scores followed by avoid and replaced strategies.
[234]	China	Asia	MCDM and GP	14	Used MCDM and GP for ranking of strategies based on SWOT.	For developing of hydrogen economy in China, need to analyze external and internal environment of hydrogen economy.	For analysis and evaluated of hydrogen economy, this study used SWOT model and fuzzy MCDM.	Results of this study proposed nine effective strategies for development of hydrogen economy in China based on SWOT model.
[235]	Australia	Oceania	Fuzzy AHP	3	Used FAHP for evaluation of ecosystem management strategies.	For assessment of recreational fishing, need to solve some conflicts interests related to the management of recreational fishing.	This study for evaluating of management strategies integrated decision support system and fuzzy AHP.	Findings of this study demonstrated that, the proposed decision support system is the valuable technique for assessing management strategies regarding to coral reef environments.

**Table 14**  
Distributed papers based on construction and environmental management.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[245]	Turkey	Europe	ANP	3	Used ANP for fuels evaluation based on residential heating	For developing of energy demands related to fuels for residential heating, there some factors which are important for implementing of energy policy such as; energy prices, society structural development and technological development.	This study for developing and evaluating of suitable fuels for residential heating used ANP technique with integrate group decision making.	Results of this study found that, pollution cost elimination, effects of morality, clean environment and greenhouse effect is the most important criteria in social, environmental, political and economic aspects, and economical heating is the most important opportunity.
[246]	Portugal	European union	MCDA	6	housing evaluation	Need to suitable methodology for assessing of urban built space due to increase of housing demand, construction and environmental requirements and scares housing lands.	For evaluation of urban built space, this study suggested the MCDA techniques, GIS and human computer interface.	Results of this study indicated that, the presented method offered to users the user-friendly and flexible environment for helping housing assessment by consumers and experts.
[247]	Iran	Middle East	SWARA and WASPAS	3	Employed SWARA and WASPAS for regions priority assessment of solar projects	For implementing of solar energy projects need to consider several environmental, economic, social, technical and risk criteria rather than finding of suitable regions.	For solving problem related to identify the best regions for solar energy projects implementation this study used two MCDM techniques including SWARA and WASPAS.	Findings of this study found that, the best region for implementation of solar energy projects in Iran the first rank was Yazd.
[248]	Italy	European union	ELECTRE III	27	Applied ELECTRE III for selection of the best sites for EIAP.	Due to complex and long process there is problem for choosing the best incinerator location for store ashes and other wastes in Italy.	For activation of an EIA procedure, incinerator and other waste-disposal this study used two MCDM techniques for choosing the best location.	Results of this study demonstrated that; proposed model analysis the decision process and synthesizes the results of MCDA intervention.
[249]	UK	European union	MCA	4	Used MCA for evaluation of hydropower project	There is lack in suitable tools for sustainability assessment related to hydropower project which can evaluate all social, economic and environmental criteria simultaneously.	For evaluating of sustainability criteria this study proposed a novel method for assessment of hydropower projects by employ MCA technique.	Findings of this paper illustrated that; for development of hydropower projects there is clear trade-off based on economic, social and environmental criteria.
[250]	UK	European union	COPRAS	20	Applied COPRAS for evaluation of the housing affordability.	There is need to consider economic, environmental and social criteria related to housing sustainability for improve life quality and community sustainability..	For assessment of affordability of sustainable housing, this study used MCDM approach based on COPRAS.	Results of this study found that, for affordability of housing in the selected areas, need to more focus on environmental and social criteria than economic criteria.
[251]	Sri Lanka	Asia	Fuzzy TOPSIS	3	Analyzed of designing HESs by applied Fuzzy TOPSIS.	Due to global issues related to fossil fuel resources depletion and greenhouse gas emissions need to find the optimal design of hybrid energy systems (HESs).	For design process of hybrid energy systems (HESs) this study integrated MCDM technique and multi-objective optimization.	Results of this study found that, a new proposed model was useful for determine weights of objectives for present a details view.
[252]	Greece	European union	ELECTRE III	22	Employed ELECTRE III for selection of the best construction location facility.	There is need to identify of optimal location related to demolition waste management and construction with respect environmental, technological and economic criteria in construction industry.	For selecting and assessing of the best locations for demolition waste management and construction , this paper used MCDM approach by consider of environmental, technological and economic criteria.	Outcomes of this study found that; Litochoro is the best location followed by Veria and Polikastro for development of Units of Alternative Management (UAMs).
[253]	Italy	European union	AHP	8	Utilized AHP for space heating systems selection.	There are several conflicting solutions and objectives for space heating of industrial buildings which need to consider the economic optimization models.	For selecting the best space heating systems in the industrial buildings this study used MCDM technique.	Results of this study found that; investment costs were the most important criteria for industry, while operational cost and qualitative attributes were the most important in homes.
[254]	India	Asia	fuzzy AHP and TOPSIS	6	Used FAHP-TOPSIS for selection of thermal power plant location.	There is problem in location selection of thermal power plant (TPP) which influence on economic operation	For ranking, selection and evaluating of thermal power plant (TPP) location this study used STEEP-fuzzy AHP-TOPSIS	Findings of this study based on sensitivity analysis found that; cost and availability of resources were the most (continued on next page)

Table 14 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[255]	Turkey	Europe	TOPSIS and AHP	9	Used AHP and TOPSIS for assessment of safety management system.	regarding to plant and sustainable development of the region. Due to important of ship safety and evaluate effectiveness of safety management system (SMS), need to attain maritime regulatory compliances with some requirements of ship operational for perform the safe operations on-broad ships. Need to the efficient modeling to manage urban storm-water runoff related to sustainable urban drainage system.	by consider environmental, technical, political and economical criteria. For implementation of safety management in on-broad ships, this study measure effectiveness of this system by using MCDM techniques.	important criteria for selection of thermal power plant (TPP) location. Results of this study found that, crew injuries, detentions number and major non-conformities were the most important factors in evaluation of ship safety management system.
[256]	Spain	European union	FAHP	9	Used FAHP for urban pervious pavements selection.	Need to quality evaluation framework for reuse and recycling parts of end-of-life wheel loader in order to environment impacts. Need to evaluate the technologies of energy related to road transport sector in European Union due to second rank greenhouse gas emissions.	For selection of project contractors this paper proposed the integrated method based of MCDM and this paper presents a multi-criteria approach and MIVES method.	Finding of this study indicated that; the proposed model is useful for decision maker for selection of the most appropriate types of pavement.
[257]	China	Asia	FAHP	9	Evaluated of quality evaluation for development of management system by used FAHP.	Need to quality evaluation framework for reuse and recycling parts of end-of-life wheel loader in order to environment impacts. Need to evaluate the technologies of energy related to road transport sector in European Union due to second rank greenhouse gas emissions.	For evaluation of reusability of recycling parts this study used MCDM technique.	Findings of this paper found that; this proposed system can help to management for process recovery and enhance the workflow efficiency.
[258]	Lithuania	European union	TOPSIS	6	Used TOPSIS for evaluation technologies of road transport.	Need to evaluate the technologies of energy related to road transport sector in European Union due to second rank greenhouse gas emissions.	For evaluation of energy technologies related to transport road sector, this paper used MCDM techniques such Interval TOPSIS.	Finding of this study indicated that; some factors influence on transportation overall level such as quality, extent and capacity, in addition; results found that; renewable-based battery-electric vehicles was the best rank based on holistic and environmental approach.
[259]	Lithuania	European union	TOPSIS	4	Applied TOPSIS for assessment of technologies building based on small scale CHP.	There is need to replace the old capacities such as Russian gas and oil and supply new technologies for future energy in Lithuania such as CHP technologies.	For assessment new technologies related to future energy such as CHP technologies, this paper applied MCDM technique.	Results of this study found that, stirling engines; micro-turbines and PEM fuel cells were the most important sustainable small CHP technologies.
[260]	China	Asia	DEMATEL and fuzzy MULTIMOORA, FTOPSIS, FVIKOR	7	Applied DEMATEL FTOPSIS, FVIKOR and fuzzy MULTIMOORA for evaluation of HCW technologies.	Selection of technology related to disposal of Health-care waste (HCW) is complicated problem in developing countries.	For assess, select and ranking the optimal technology related disposal of Health-care waste (HCW), this study consider the qualitative and quantitative criteria by using MCDM techniques.	Findings of this paper indicated that, steam sterilization was the optimal technology related disposal of Health-care waste (HCW) treatment.
[261]	Australia	Oceania	MCA	12	Used MCA for ranking and assessment of regional conservation planning.	Due to increase on some regional-scale ecological restoration such as native vegetation quality, need to ranking and evaluating the farm scales, regional conservation priorities and assesses how these maps map influence farm-scale actions in Western Victoria.	For raking and evaluating of regional conservation, this study used the MCA methods.	Results of this study found that regional conservation has higher value by support regional natural resource management decision-making rather than as a tool to influence farm-scale actions.
[262]	Lithuania	European union	SWARA-TODIM	5	Integrated SWARA-TODIM for ranking of wall insulation in building	The high amounts of energy in Europe spend in old buildings, in this regard, there is need to retrofit energetically non-efficient of buildings.	For analyzing of efficiency of building modernization, this study used MCDM techniques by emphasis on thermal insulation of external walls.	Findings of this paper found that, duration of works, price, water vapour diffusion, payback period and energy losses were the most important factors.
[263]	Lithuania	European union	ARAS, SAW, TOPSIS and COPRAS	8	Evaluation of built and human environment by used SAW, ARAS, TOPSIS and COPRAS	There is a problem of defining intelligent built environment in the case of several stakeholders.	The COPRAS method was presented for designing a number of the alternative versions of an intelligent built environment.	An original model was proposed for a complex analysis of the intelligent built environment.
[264]	Lithuania	European union	COPRAS	13	Applied COPRAS for intelligent built environment	There is need to consider the building renovation and micro, micro and meso	For consider and integrate the building renovation and micro, micro and meso	The MCA of the projects assessed by ARAS SAW, and COPRAS techniques (continued on next page)

Table 14 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[265]	Lithuania	European union	COPRAS	22	to improve inhabitant's quality of life and to satisfy inhabitants	human factors building environments.	human factors this paper combined three MCDM techniques such as ARAS, SAW, TOPSIS and COPRAS.	yielded the same results. The optimal alternative was the conservation and restoration of Shumen Fortress and the least optimal alternative was the establishment of "Sofia Arsenal" museum for contemporary art.
					Applied COPRAS for ranking of residential areas.	Many countries in the world face problems of sustainable development in the city and residential areas.	The application of a multipurpose evaluation method, COPRAS, allowed the authors to establish the ranks (or the priority order) of residential areas in respect of their sustainability.	Based on multipurpose evaluation method, COPRAS, the most sustainable residential area was determined and evaluated by 22 sustainability development indices.

generally associated with various uncertainties and complexities that are being further amplified due not only to dynamics and interactions amongst different sub-systems, but also their association with economic penalties at the time that different overriding policies are violated. Consequently, it is desired to develop robust and efficient systems analysis methodologies that can address the above-mentioned complexities.

The approaches are detected to be most important in energy management areas followed by 13 sub-areas such as environmental impact assessment, energy management, waste management, sustainability assessment, renewable energy, energy sustainability, land management, green management topics, water resource management, climate change, strategic environmental assessment, construction and environmental management and other environmental areas.

This study combines the dimensions of uncertainty considered in energy decision-making processes and MCDM techniques. All studies have taken into consideration various aspects of energy management in different sub-areas with great planning level, e.g., a local or nationwide level. Weights of criteria directly influence on the decision-making consequences of energy systems substitutions. They will be mainly used to energy systems decision making as they assess the comparative significance accurately minus decision makers. MCDM approaches were extensively used in energy systems decision making that considers multi-criteria. Usually hybrid MCDM and FMCDM in the integrated approaches and AHP and fuzzy AHP in the individual methods are the most prevalent widespread technique that the basic biased sum technique is still simple in MCDM difficulties. Fuzzy set methodology was progressively used for caring the qualitative standards and the vagueness or fuzziness characteristic in the data. The calculation and evaluation in energy systems decision making is usually obtained in a MCDM approaches. It is essential that a few dissimilar classes of techniques and approaches are used to get the ranking instructions of energy systems' substitutes and ensure that the validity of MCDM approaches is confirmed. It is supposed that the consequences got by the other mathematics approaches are more balanced and more mathematics approaches will help in the energy management problems in the future. It can recommended that MCDM can develop an influential instrument for solve problems in the energy management.

Table 18, Figs. 4–6 show the MCDM methods development trend in energy management issues based on three main categories including crisp, fuzzy or grey numbers and hybrid methods. The following table provides information about the reviewed different MCDM methods amount applied in overview articles. Taken into account MCDM methods were used in traditional original form (crisp) or were used extensions applied fuzzy sets or grey systems and how many times these methods have been used in hybrid systems.

Table 18 represented the frequently of MCDM methods such as fuzzy sets, grey systems methods and hybrid MCDM that applied for solving problems in energy management issues. The table shows that the traditional form (crisp) mainly used for AHP, PROMETHEE, ELECTRE and TOPSIS methods, because these methods are old, well-known and widely used in many fields such as energy management issues. However, using fuzzy sets mostly applied AHP and TOPSIS methods, but usually in hybrid MCDM approaches two or three MCDM methods integrated such as AHP and TOPSIS with ELECTRE or PROMETHEE methods. Pohekar and Ramachandran [20], also found that AHP with 20% of published papers followed by PROMETHEE and ELECTRE techniques was the significant technique for ranking the energy management alternatives. For example; some previous scholars employed DM techniques and approaches to improve problems in this field such as Mourmouris and Potolias [77] employed MCDA for assessment of energy planning and renewable energy sources. Mourmouris and Potolias [77], evaluated the performance by fuzzy ANP, AHP and TOPSIS for building energy systems. Catalina, Virgone [78], analyzed energy systems by using ELECTRE III. Lee, Mogi [79] used FAHP and DEA for allocation of R & D resources based

**Table 15**  
Distributed papers based on other energy management areas.

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[266]	Portugal	European union	AHP	9	Applied AHP and GIS for spatial data analysis	Incineration of municipal solid waste (MSW) needs to finding and assessment the best location with respect to minimize the health, economic, social, environmental and technical costs. Due to exogenous factors and long production periods forest planning usually under some uncertainty and risk.	For assessment land suitability related to plant siting this study integrated MCDM technique with GIS.	Results of this paper indicated that, Praia municipality is the best option for build the MSW incineration plant with respect to environmental, social-economic and technological criteria. Findings of this paper found that, integrate use of multi-criteria analysis and ecosystem approaches were suitable for evaluation of performance an adaptive preferentiality of forest management alternatives.
[272]	Finland	European union	MCA	7	Used MCA for stand treatment programs evaluation	There is need to simultaneously consider all different environmental, economic and social aspects in selection of ecosystems restoration programs metrics.	Developed model for evaluation of different programs related to stand treatment in the boreal forest based on MCA.	Findings of this study found that, there are no differences between the MAUT and ProMAA in the ranking of metrics and predicted utility.
[273]	USA	Northern America	ProMAA and MAUT	43	Used MCDA method for selection of programs for ecosystem restoration	There are several risks factors can influence on developing of wetland such as ecological risks factors.	For choosing the optimal metrics of ecosystem restoration this study used MCDM techniques based on MAUT and probabilistic multi-criteria acceptability analysis.	Results of this study found that; change in natural habitat and sedimentation and filling factors were high and low raking factors respectively.
[267]	Iran	Middle East	AHP	17	Implemented of AHP for evaluation of ecological risk factors.	Erosion control of soil is the main topic and there is not any system of production of soybean widely developed.	For identification of stress factors related to ecological aspects this study used ecological risk assessment (ERA), GIS and MCDM techniques.	Results of this study found that, there are interest of high influence on water and soil management factors on the environmental aspects and strong conflict between economic and environmental aspects.
[274]	Argentina	South America	LGP and Compromise programming	17	Applied LGP and Compromise programming for assessment of the conflicts and trade-off among environmental, economic and social interests.		For evaluation of soil erosion control based on economic, social, environmental aspects by using MCDM techniques.	Results of this study indicated that, leave in intact present the best environmental outputs for future decommissioning.
[275]	Australia	Oceania	Multi-criteria Approval	5	Evaluation of oil and gas infrastructure by used Multi-criteria Approval method	There is need to consider financial, socio-economic, environmental, health and safety aspects for assessment and comparison of all options of decommissioning.	This study to assess and compare all alternative related to decommissioning options used MCDM approaches.	Results of this study found that; gas-steam integrated cycle CCHP system is the best option among other five options.
[276]	China	Asia	Fuzzy MCDM	4	Used fuzzy MCDM for evaluation of CCHP systems.	Need to identify the best practical decision making model for cooling, heating and power (CCHP) system by focus on different energy sources.	Proposed an assessment model by using fuzzy MCDM for evaluate of CCHP systems based on environment, technology society and economic criteria.	Findings of this paper found that; relying on new coal power plants, Maximum Renewable and Coal were the most important ranks.
[277]	Portugal	European union	MCDA	13	Used MCDA for assessment of electricity production scenarios.	There are some high possible way for develop renewables energy, but there is high uncertainty which energy can use as power generation system in Portugal.	For raking of different scenarios this study used MCDA technique for ranking of 13 criteria technical, job market quality of life of local populations, economic and environmental issues.	Results of this study found that; the proposed methodology can help to firms for develop their strategies related to CO2 management on the supply chain level.
[268]	Germany	European union	ANP	4	Used ANP for assessment of CO2 management reduction.	Need to proposed methodology for manufacturing firms for assess which supplier are the best partners which can cooperation in reduction and implementation CO2 reduction management method.	For assess and select the optimal supplier this paper used MCDM technique.	Findings of this study found that; the proposed methodology can help to firms for develop their strategies related to CO2 management on the supply chain level.
[278]	Iran	Middle East	AHP and fuzzy algorithm	4	Selected of Prime mover by employed AHP and fuzzy algorithm.	Need to consider environmental, technological, economical, and social for selection and evaluation of the best prime mover for a micro-CCHP system.	For choosing and selecting the best prime mover for micro-CCHP system in the residential building, this study used fuzzy MCDM approaches in five different climates.	Results of this study found that; best to worst prime movers were in this study included of the internal combustion, sterling engine, conventional separate production and micro-gas turbine.

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Table 15 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[279]	Turkey	Europe	FMCDM	4	Utilized fuzzy measure and fuzzy integral for selection of best HCW treatment.	Management of health-care waste (HCW) is the important issue in developing countries and need to attention on health, public and environmental concerns.	Proposed a novel model for assess of HCW treatment alternatives based on MCDM approaches.	Outcomes of this paper found that, steam sterilization is best rank of HCW treatment followed by microwawe.
[280]	Canada	Northern America	fuzzy MCDA	3	Employed fuzzy MCDA for selection of the best scenario in WRM and planning	Need to present new general framework based on DSS for water resources management planning in Haihe River Basin.	Presented a novel methodology for developing of water resources management planning.	Results of this paper found that water supply scenario had the best rank among other scenarios for solving problems related to water resources scarcity.
[269]	India	Asia	FAHP and fuzzy multi-objective LP	5	Employed FAHP and fuzzy multi-objective LP for low carbon development	There is need to consider the carbon emission factor for evaluation of suppliers.	Proposed new fuzzy MCDM for evaluation of suppliers based on quality rejection percentage, cost, late delivery percentage, gas emission demand and greenhouse demand.	Results of this study indicated that; quality, cost and carbon footprint were the import factors in selection of suppliers.
[281]	Spain	European union	ANP	56	Applied ANP for selection of PV solar power projects.	There are several risks of time delays for selection of projects related to the selection of photovoltaic (PV) solar power.	Select and assess the best projects of photovoltaic (PV) solar power for investment and minimize of risks by using MCDM technique.	Result of this study demonstrated that; changes in energy policy, social consequences resulting from land acquisition, delays in the obtaining of the EIS, thefts, legislative changes in the EIS, obtaining of the local body approval, revenue estimation based on effective solar radiation time, delays in the obtaining of the local body approval were the most important factors in selection of PV solar power projects.
[282]	China	Asia	Fuzzy AHP and Fuzzy TOPSIS	11	Applied FAHP and FTOPSIS for ranking of hydrogen production technologies.	It is very important to rank the various hydrogen production technologies in order to development of hydrogen economy in China.	For identify and ranking of the criteria factors various hydrogen production technologies this paper used fuzzy MCDM.	Outcomes of this study found that; the hydropower-based water electrolysis and coal gasification with CO2 capture were main important hydrogen production for development of hydrogen economy in China.
[283]	USA	Northern America	AHP	7	Applied AHP for evaluation of SMR deployment in developing countries.	There is need to focus on small modular nuclear reactors (SMRs) as emerging energy technology in developing economies.	For develop of emerging economics, this study used MCDM technique by assess the market conditions for SMR development.	Results of this study demonstrated that, some countries with increasing energy demand and GDP have a strong energy production from high GHG sources; infrastructure and governmental policies encourage foreign investment on SMR deployment in future.
[284]	Italy	European union	TOPSIS	3	Utilized TOPSIS for flood mitigation.	There is need to proposed framework for evaluation of recovery measure and score portfolios of flood mitigation.	For evaluation of recovery options and flood data and mitigation, this study used an innovative operational DSS.	Outcomes of this study found that; development of evacuation plans and construction of sand dunes are the best mitigation option, and insurance schemes and construction of sand dunes and development of evacuation were the best recovery options.
[285]	India	Asia	AHP	8	Applied AHP for selection of the best IDMs for GCPVS	There are main challenges on detection islanding in the grid-connected photovoltaic due to make hazardous to both utility personal and components of the system.	For evaluate of different islanding detection method ad identify the suitable selection for grid-connected photovoltaic system (GCPVS) this study applied MCDA technique.	Results of this paper indicated that; with respect to implementation cost, rate of change of frequency had the first rank.
[286]	Spain	European union	Fuzzy TOPSIS	6	Applied Fuzzy TOPSIS for evaluation of PV cells.	Due to high cost of implementation of solar energy, countries cannot use this	For solving this problem, this study tried to analysis criteria related to solar	Outcomes of this paper found that; advanced thin film III–V technology

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Table 15 (continued)

Author	Nationality	Region	Technique	No. of criteria	Research purpose	Gap and contribution	Solution and modeling	Results
[270]	USA	Northern America	fuzzy AHP	18	Evaluated of fire risk based on FAHP.	One of major cause of environmental and ecological disturbance is the forest fires.	energy for finding the best photovoltaic cell based on fuzzy MCDM techniques. For showing the forest fire risk, this study integrated GIS with fuzzy MCDM technique.	with monitoring systems with solar concentration is the best alternative for using og solar systems. Findings of this study found that; socioeconomic factors followed by vegetation, climate and topography had the highest rank respectively.
[271]	Hong Kong	Asia	AHP	21	Assessed proposals based on urban renewal by used AHP.	Need to enhance of the physical environment conditions for urban renewal due to lack in previous published papers in urban renewal proposal assessment.	For identify the most important proposal related to sustainable design of urban renewal, this study applied MCDM technique.	Outcomes of this paper indicated that; environmental sustainability had the highest rank compare with other aspect and green design factor had the first rank compare with other factors.
[287]	China	Asia	FMSGDA	5	Presented FMSGDA for assessment of ecological risk management	There are several serious alternatives of watershed ecological risk management, which need to consider in terms of multiple complex criteria.	Analyzed the alternatives related to watershed ecological risk management by proposing new fuzzy MCGDM.	Results of this paper found that; the proposed model is suitable for analyzing of alternatives related to watershed ecological risk management.

Table 16

Distribution of papers based on the name of journals.

Name of journal	Number	Percentage (%)
Renewable and Sustainable Energy Reviews	32	16.33%
Journal of Cleaner Production	13	6.63%
Waste Management	10	5.10%
Energy Policy	9	4.59%
European Journal of Operational Research	8	4.08%
Ecological Indicators	7	3.57%
Expert Systems with Applications	7	3.57%
Environmental Modeling & Software	7	3.57%
Journal of Environmental Management	5	2.55%
Energy	5	2.55%
Renewable Energy	5	2.55%
Resources, Conservation and Recycling	4	2.04%
Environmental Impact Assessment Review	4	2.04%
Energy and Buildings	3	1.53%
Environmental Monitoring and Assessment	3	1.53%
Applied Energy	3	1.53%
Ecological Economics	3	1.53%
Omega	3	1.53%
Stochastic Environmental Research and Risk Assessment	3	1.53%
Journal of civil engineering and management	3	1.53%
Safety Science	2	1.02%
International Journal of Production Economics	2	1.02%
Building and Environment	2	1.02%
Energy Sources, Part B	2	1.02%
Water resources management	2	1.02%
Environmental Science & Policy	2	1.02%
Decision Support Systems	2	1.02%
International Journal of Sustainable Energy	1	0.51%
Clean Technologies and Environmental Policy	1	0.51%
Computers & Industrial Engineering	1	0.51%
Environmental Earth Sciences	1	0.51%
Journal of Multi-Criteria Decision Analysis	1	0.51%
Socio-Economic Planning Sciences	1	0.51%
Civil Engineering and Environmental Systems	1	0.51%
Computers in Industry	1	0.51%
The British Accounting Review	1	0.51%
Journal of Environmental Science and Health	1	0.51%
Engineering Applications of Artificial Intelligence	1	0.51%
Agricultural Water Management	1	0.51%
Sustainable Energy Technologies and Assessments	1	0.51%
Bioresource technology	1	0.51%
Technological and Economic Development of Economy	1	0.51%
Transportation Research Part D: Transport and Environment	1	0.51%
Ocean & Coastal Management	1	0.51%
Annals of Operations Research	1	0.51%
Fuzzy sets and systems	1	0.51%
Automation in Construction	1	0.51%
International Journal of Computational Intelligence Systems	1	0.51%
Social Indicators Research	1	0.51%
The International Journal of Life Cycle Assessment	1	0.51%
Sustainable Cities and Society	1	0.51%
Computers, Environment and Urban Systems	1	0.51%
Land Use Policy	1	0.51%
Ecological Engineering	1	0.51%
International Journal of Strategic Property Management	1	0.51%
Science of the Total Environment	1	0.51%
Computers and Electronics in Agriculture	1	0.51%
International Journal of Project Management	1	0.51%
Agricultural systems	1	0.51%
Environment International	1	0.51%
Journal of Environmental Engineering and Landscape Management	1	0.51%
Energy Conversion and Management	1	0.51%
Urban Climate, 10, Part 1	1	0.51%
Optimization Letters	1	0.51%
Forest Ecology and Management	1	0.51%
Applied Thermal Engineering	1	0.51%
Progress in Natural Science	1	0.51%
Process Safety and Environmental Protection	1	0.51%

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**Table 16** (continued)

Name of journal	Number	Percentage (%)
Journal of Business Economics and Management	1	0.51%
Applied Soft Computing	1	0.51%
Journal of Manufacturing Science and Technology	1	0.51%
Procedia Engineering	1	0.51%

on efficiently energy, Polatidis, Haralambopoulos [80], integrated ELECTRE IV, PROMETHEE I and PROMETHEE II for a wind-hydro hybrid energy evaluation.

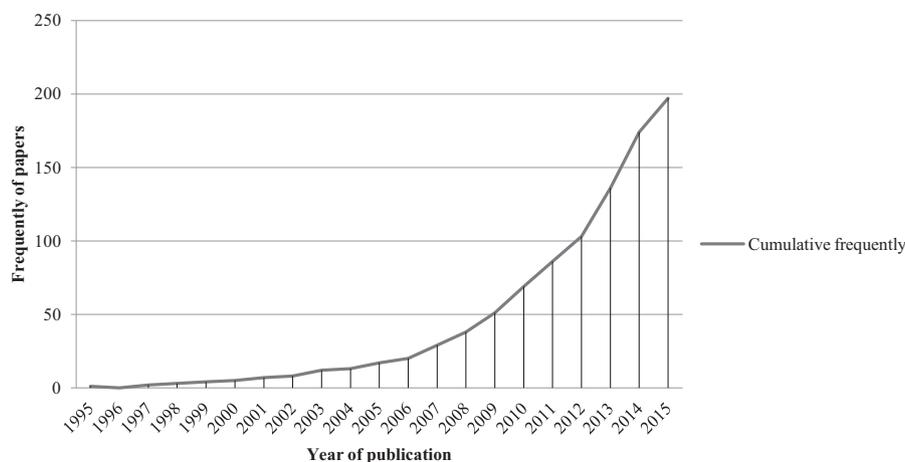
There are various theories for handing imprecise information like neutrosophic sets theory and intuitionistic fuzzy set theory. These theories can handle one feature of imprecise problem in the one framework. Smarandache [288] and Atanassov [289] introduced the neutrosophic sets theory and intuitionistic fuzzy set theory in 1980 and 1986 respectively. These two theories successfully applied to solve challenges in various application areas using MCDM methods. These two theories could be successfully adapted to analyze energy management problems, but based on our review paper only few of previous published papers have used these theories, therefore, using these theories would help better to assess uncertainties, risky environment and solving energy management problems. Energy management problems are typically influenced by extensive kinds of uncertainties. When selecting an MCDM approach for energy management, it is therefore important to consider the method’s ability to take uncertainty and risk preferences into account. However, the ability of the methods to account for uncertainties should be weighed against their other weaknesses and strengths. In fact, selecting the best MCDM approach for a specific application is essentially an MCDM problem on its own.

It is well known that individual MCDM methods can make different selectable options ranks. Usually, analyzed articles only used one method. Therefore; it is recommended to use hybrid MCDM techniques [290] and use the results for final decision. In this regard, for integrating process future paper can be applied some old techniques such as Borda and Copeland methods, dominance theory [291] and so on. According to our review paper in energy management problems, for development of hybrid methods previous published papers commonly applied a single method to determine the criteria weights and few of them have integrated the subjective and objective criteria weights [292]. For this purpose, future studies can integrate traditional AHP [293], entropy [294], expert judgement [295] methods. Moreover, recently, some scholars proposed some new methods SWARA [296], FARE [297], CILOS and IDOCRIW [298] which can be used successfully.

Results of our review paper indicated that, there is lack of attention regarding the preparation of decision making matrix and also lack of justification which how and why they choose one or other methods for data normalization. In this regards, only few of previous studies are given justification for normalization method in terms of comparative calculations and sensitivity analysis [299–301]. In the literature, several aggregation operators have been developed by researchers to aggregate numerical data in different situations. Currently, more than 90 approaches of aggregation operators studied. The main aim of the aggregation phase is to integrate a set of measures in such a way that the final aggregation output takes the entire single criterion into account. The final selection of classifications naturally derives from this set of overall degrees and therefore valuable classifications are not discarded for having failed to meet few criteria. In many real life decision making situations, the available information is vague or imprecise. To adequately solve decision problems with vague or imprecise information, fuzzy set theory and aggregation operator

**Table 17**  
Distribution of papers based on the authors’ nationality.

Name of country	Number	Percentage (%)	Name of country	Number	Percentage (%)
Turkey	15	7.61%	Netherlands	2	1.02%
China	14	7.11%	Romania	2	1.02%
United States	14	7.11%	Brazil	2	1.02%
Greece	13	6.60%	Sweden	2	1.02%
Australia	12	6.09%	Austria	2	1.02%
Iran	12	6.09%	Hong Kong	2	1.02%
Lithuania	11	5.58%	Nepal	1	0.51%
Canada	10	5.08%	Belgium	1	0.51%
UK	10	5.08%	New Zealand	1	0.51%
Germany	9	4.57%	Slovenia	1	0.51%
Italy	8	4.06%	Ireland	1	0.51%
India	8	4.06%	Trinidad and Tobago	1	0.51%
Taiwan	7	3.55%	France	1	0.51%
Spain	7	3.55%	Japan	1	0.51%
Portugal	5	2.54%	Bosnia and Herzegovina	1	0.51%
Finland	4	2.03%	Switzerland	1	0.51%
Republic of Korea	3	1.52%	Sri Lanka	1	0.51%
Denmark	3	1.52%	Argentina	1	0.51%
Malaysia	3	1.52%	Croatia	1	0.51%
Serbia	3	1.52%	Poland	1	0.51%



**Fig. 2.** Distribution papers based on year of publication.

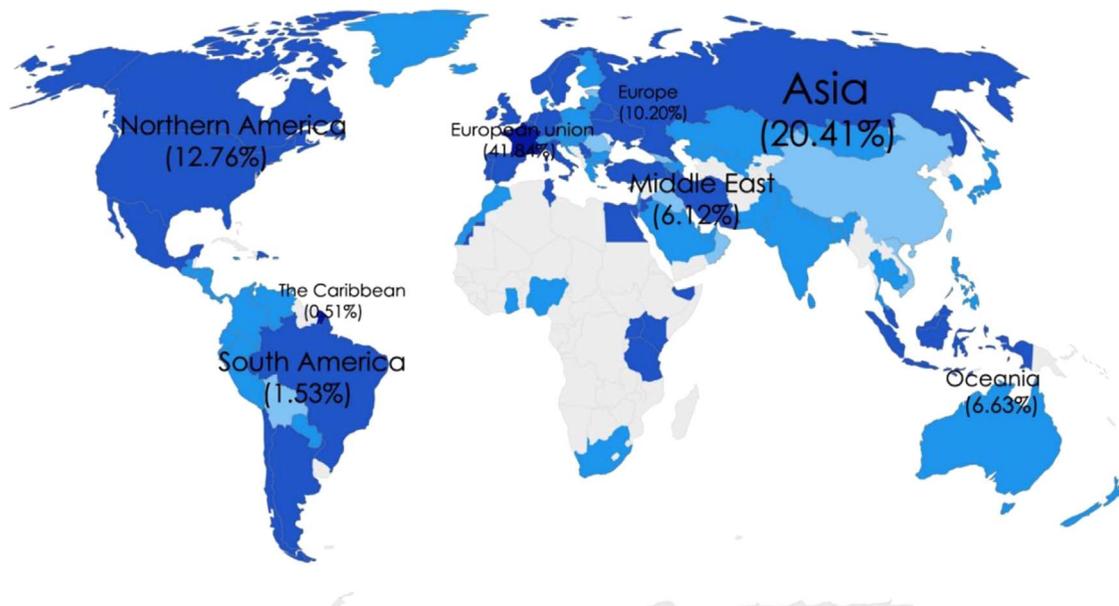


Fig. 3. Distribution papers based on region.

Table 18  
MCDM methods development trend.

MCDM	Crisp	Fuzzy or Grey numbers	Hybrid Methods
AHP	48	28	22
ANP	10	9	6
PROMETHEE	19	–	10
TOPSIS	12	13	12
ELECTRE	18	1	11
VIKOR	6	2	3
DEA	2	1	2
DEMATEL	4	1	5
COPRAS	6	1	4
ARAS	2	1	3
TODIM	1	–	1
SWARA	3	–	3
MULTIMOORA	2	2	1
MAUT	2	3	2
OCRA	1	–	–
WASPAS	1	–	1
SAW	1	–	1
WSM	1	1	2
DELFI	–	1	1
OWA	2	–	2
MAVT	1	–	–
TOTAL	142	64	92

theory have become powerful tools. In last four decades, decision making theories and methods under fuzzy aggregation operator have been proposed and developed for effectively solving the decision making problems and numerous applications have been reported in the literature. While various aggregation operators have been suggested and developed, there is a lack of research regarding to application of decision making theories and methods under fuzzy aggregation operator in energy management issues. Therefore; it is recommended to use these techniques for solving the energy management problems. In this regard, future papers can focus on the integrating MCDM methods with other types of fuzzy theory sets, fuzzy integrals and aggregation operators such as; hesitant fuzzy Choquet integral, hesitant fuzzy Choquet ordered geometric (HFCOG) operator, hesitant fuzzy Choquet ordered averaging (HFCOA) and other fuzzy integrals and aggregation operators' techniques. Moreover; future studies can combine MCDM techniques with energy management

qualitative information and quantitative data based on hesitant fuzzy linguistic term sets, discrete fitting aggregation and simplified optimal discrete fitting aggregation. In case of interval-valued intuitionistic fuzzy, future scholars can use MCDM methods for integrating with Interval-valued intuitionistic fuzzy weighted arithmetic aggregation, the interval-valued intuitionistic fuzzy ordered weighted aggregation, interval-valued intuitionistic fuzzy hybrid aggregation operators. Furthermore, future studies can combine the MCDM methods with fuzzy ordered weighted operators like induced interval-valued intuitionistic fuzzy ordered weighted geometric, fuzzy ordered weighted averaging (FOWA) operator, the fuzzy ordered weighted geometric (FOWG) operator and other fuzzy ordered weighted operators.

### 6. Concluding remarks

This review paper is aimed to review previous studies that applied the MCDM approaches in various areas of energy management and are published duration of 1995 until 2015 in 72 international scholarly journals most related to energy management fields indexed in Web of Science database. This review paper aimed to classify published papers into 13 main areas: environmental impact assessment, energy management, waste management, sustainability assessment, renewable energy, energy sustainability, land management, green management topics, water resources management, climate change, strategic environmental assessment, construction and environmental management and other energy management areas. In the field of environmental impact assessment, outcomes demonstrated that 31 papers use MCDM approaches. Furthermore, in the area of energy management, finding indicated that 21 studies have MCDM techniques. Additionally, in the field of construction and environmental management, 21 papers have implemented MCDM approaches.

Based on review findings, 55 studies combined hybrid MCDM and fuzzy MCDM in various fields of energy management, 49 articles applied fuzzy AHP and classical AHP, moreover, 25 papers used MCDA and MCA approaches. Regarding to journals distribution, findings found that; journal of Renewable and Sustainable Energy Reviews had the first rank among 72 journals with 32 papers most related to the MCDM approaches in various fields of energy management. Regarding to nationality of authors this study found that 40 countries or nationalities used MCDM approaches into 13 various fields which the highest contribution was from Turkey. .



While this review paper is rigorously completed, there are some limitations which can present some suggestions for futures review papers. This review papers classified selected papers into 13 fields of energy management, it is suggested that future papers can review and classify papers in different areas and sub-areas. In addition; our review paper only focused on English scholarly journals rather than other languages, therefore; future review papers can consider and focus on other languages, though; we believed that our paper is very comprehensive and attempted to majority of published papers in various fields of energy management. This present paper reviewed and classified selected papers by focusing on several functions such as; the authors, publication year, nationality of authors, region, technique and application, number of criteria, research purpose, gap and contribution, solution and modeling, results and findings, it is recommend to future papers by focusing on different functions. In this regard; this review paper presented some opportunities to finding gaps in the study that can be addressed for further study directions.

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