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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 of 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 therefore 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 discusses 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