

A review of multi criteria decision making (MCDM) towards sustainable renewable energy development



Abhishek Kumar^{a,*}, Bikash Sah^b, Arvind R. Singh^c, Yan Deng^a, Xiangning He^a, Praveen Kumar^b, R.C. Bansal^{d,*}

^a College of Electrical Engineering, Zhejiang University, China

^b Department of Electronics and Electrical Engineering, IIT Guwahati, India

^c Department of Electrical Engineering, VNIT, Nagpur, India

^d Department of Electrical, Electronics and Computer Engineering, University of Pretoria, South Africa

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ABSTRACT

In the current era of sustainable development, energy planning has become complex due to the involvement of multiple benchmarks like technical, social, economic and environmental. This in turn puts major constraints for decision makers to optimize energy alternatives independently and discretely especially in case of rural communities. In addition, topographical limitations concerning renewable energy systems which are mostly distributed in nature, the energy planning becomes more complicated. In such cases, decision analysis plays a vital role for designing such systems by considering various criteria and objectives even at disintegrated levels of electrification. Multiple criteria decision making (MCDM) is a branch of operational research dealing with finding optimal results in complex scenarios including various indicators, conflicting objectives and criteria. This tool is becoming popular in the field of energy planning due to the flexibility it provides to the decision makers to take decisions while considering all the criteria and objectives simultaneously. This article develops an insight into various MCDM techniques, progress made by considering renewable energy applications over MCDM methods and future prospects in this area. An extensive review in the sphere of sustainable energy has been performed by utilizing MCDM technique.

1. Introduction

Approximately 1.2 Billion people i.e. around 17% of the earth population do not have access to electricity, out of which around 635 million are located in Africa and 237 million are in India [1]. Still 2.7 billion global population is dependent on the traditional energy sources such as solidified dung cakes, firewood etc. to fulfil their energy needs [2]. Most importantly 95% of this population is from the rural areas who are deprived of modern energy resources [1,2]. This dependency on the traditional sources are not just causing adverse effects on human health but also on environment due to global deforestation and greenhouse emissions [2]. Highlighting the gravity of energy snag for sustainable development, United Nation (UN) general assembly unanimously declared the decade 2014–2024 as the “Decade of Sustainable Energy for All”, namely to “ensure access to affordable, reliable, sustainable and modern energy for all” [3]. For any developing nations, in order to achieve their development goals and to support its expanding economy, surplus energy is the main key. Nevertheless, the sustainable development provides highly reliable and affordable

energy which is also vulnerable by industries causing all types of environmental issues [4]. In order to address the environmental issues coming in the path of sustainable development, the green energy resources can play a very crucial role. Hence, for developing countries to thrive on the path of development without hampering the environment, the sustainable and renewable energy sources can be proved to be beneficial. In countries like India, around 30% energy demand is dependent on Renewable Energy Sources (RES) which include Hydro, Small Hydro Project (SHP), Biomass Gasifier (BG), Biomass Power (BP), Urban and Industrial waste (U & \$2 I) and Wind Energy [5]. Even with availability of renewable energy resources, the efficient use of energy is highly necessary. New governmental policies in many countries have been introduced mainly to transform the current energy systems to highly efficient green sustainable energy systems. In many developing nations such as India, the main aim of these policies is to maximize the renewable energy usages by enhancing the infrastructure capacity by more than 5 times from 32 GW in 2014 to 175 GW in 2022 [6]. It is very challenging to achieve such a system without proper planning which meets the aim of sustainable energy. Over the past

* Corresponding author.

E-mail addresses: abhi@zju.edu.cn (A. Kumar), rcbansal@ieee.org (R.C. Bansal).

decades, the energy planning methodology has been absolutely transformed from a single objective simple system to a more complex system due to the inclusion of multiple benchmarks, stakeholders and disagreeing aims [4]. Traditional single objective decision making which is basically concerned with either maximization or minimization of a particular element remains beneficial only in a study of small system. Current energy planning scenario has multiple objectives, definitions and criteria making it more difficult to attain a system with a perception of sustainability. Thus, an adequate planning system considering necessary political, social, economic and environmental aspects is essential to overcome rising demand of energy with a vision of sustainable development. In order to solve such complex problems concerning energy planning, multi criteria decision making (MCDM) is proved to be one of the better tool for efficient energy planning. MCDA basically originated from operations research involving a wide range of methodologies, nevertheless with an amusing rational foundation in other disciplines [7]. MCDA techniques have found wide application in public-sector as well as in private-sector decisions on agriculture resource management, immigration, education, transport, investment, environment, defence, health care etc. [8–12]. In the recent decade, MCDM has found its grounding application in energy system design. Various technical methodologies and algorithm exists to evaluate and design energy systems based on optimization of either single or multiple criteria [13–20]. The complexity involved in the various dimensions of energy systems with multiple stakeholders has been illustrated in Fig. 1.

With the increase in the complexity and multiplicity in the problem of energy planning, the single objective optimization/analysis is no longer a prevalent approach. MCDM is considered as an evaluation structure to solve environmental, socio-economic, technical, and institutional barriers involved in energy planning [22]. MCDM has become popular in energy planning as it enables the decision maker to give attention to all the criteria available and make appropriate decision as per the priority. Since a perfect design is governed by multiple dimensions, thus a good decision maker, in certain situations, may look for the parameters like technical or economical that can be compromised. MCDM helps a decision maker which quantifies parti-

cular criteria based on its importance in presence of other objectives. This work introduces some important features of the MCDM, various algorithms available and highlights its various features in context to the energy planning based on Renewable Energy Sources (RES). The MCDM techniques presented here can be used to find out an apt solution to the energy system design problems involving multiple and conflicting objectives. The paper is organized as follows: Section 2 highlights the insights in to MCDM and briefly discusses various techniques available. Section 3 illustrates the application of MCDM models in energy planning. Section 4 introduces the key performance indicators and energy schemes; Section 5 presents the discussion followed by conclusion in Section 6.

2. Multi Criteria Decision Analysis (MCDA)

As already outlined in the introduction section decision analysis is a valuable tool in solving issue as characterized with multiple actors, criteria's, and objectives. MCDM problems generally comprises of five components which are: goal, decision maker's preferences, alternatives, criteria's and outcomes respectively [4,23]. MCDM can be classified as given in Fig. 2. Based on the number of alternatives under consideration, differences can be catered between Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM); else both share similar characteristics. MODM is suitable for evaluation of continuous alternatives for which we predefine constraints in the form of vectors of decision variables.

A set of objective functions are optimized considering the constraints while degrading the performance of one or more objectives. In MADM, characteristics that are inherent are covered leading to consideration of fewer number of alternatives and thus evaluation becomes difficult as prioritizing becomes more difficult. The final result is decided by comparing various alternatives with respect to each attributes considered [12,24–26]. Different multi criteria techniques are applied in the field of renewable energy. MCDM models are another broader classification technique. The models developed are as per designer perspective. It can be a direct approach or indirect approach. In direct approach the assignment of priorities or weights are being

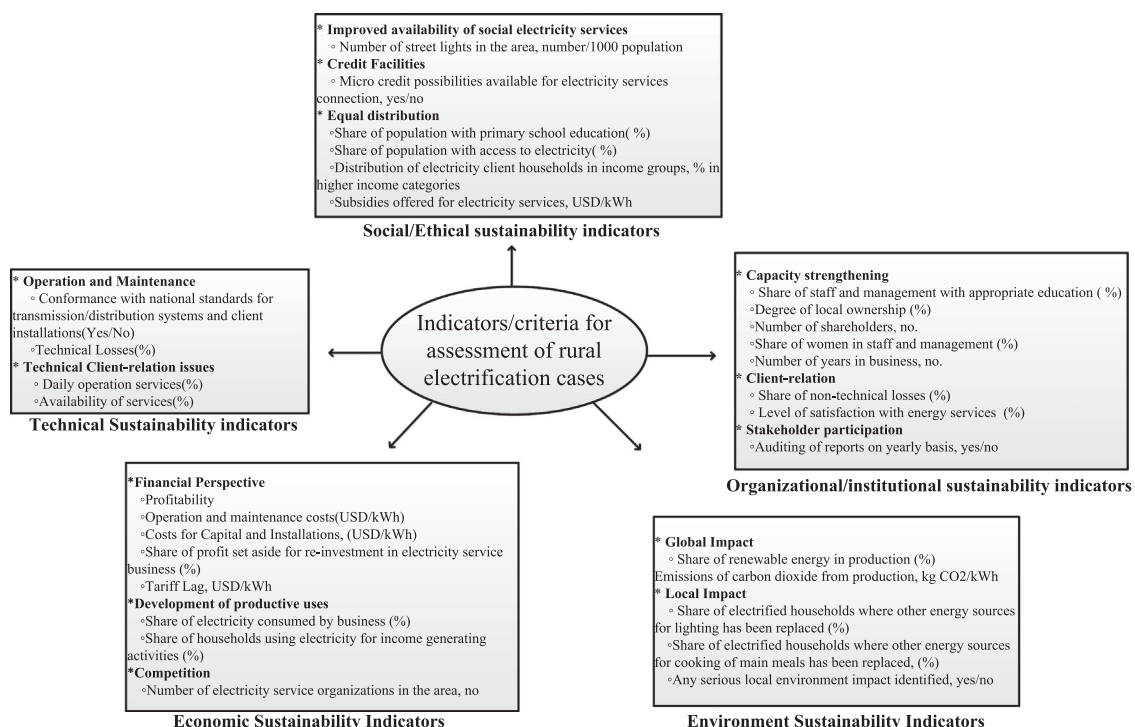


Fig. 1. Complex interaction of energy systems: An Example [21].

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