Chapter 48

Evaluation of Renewable Energy Alternatives Using Hesitant Fuzzy TOPSIS and Interval Type-2 Fuzzy AHP

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ABSTRACT
The selection among renewable energy alternatives is a fuzzy multicriteria problem with many conflicting criteria under uncertainty. In many decision-making problems, the Decision Makers (DM) define their preference in linguistic form since it is relatively difficult to provide exact numerical values during the evaluation of alternatives. Therefore, in many studies, fuzzy logic is successfully used to model this kind of uncertainty. In this chapter, the authors try to capture this uncertainty by using interval type-2 fuzzy sets and hesitant fuzzy sets. They propose a fuzzy multicriteria method for the evaluation of renewable energy alternatives, in which the priority weights of the criteria are determined by interval type-2 fuzzy AHP, and the alternatives are ranked using hesitant fuzzy TOPSIS. A case study is also given.

INTRODUCTION
Renewable energy is an inevitable alternative for sustainable economic growth and the harmonious coexistence of human and environment. Renewable energy does not pollute environment and could be recycled in nature. However, there are some challenges facing the efforts to increase renewable energy use such as their high-up front costs and related insufficient cost effectiveness. The well-known renewable energy alternatives are geothermal, hydropower, wind, solar, and biomass. Decision making among renewable energy alternatives is a multicriteria problem including many conflicting issues. When we
try to select any alternative using these criteria, we have to take into account conflicting issues among the considered criteria.

In such an evaluation, scales for many criteria are hard to measure and composed of linguistic terms. It is not easy for decision makers to assign exact numerical values for these types of criteria. Uncertainty in human preferences is successfully modeled by the fuzzy set theory. Fuzzy sets (Zadeh, 1965) can mathematically represent uncertainty and thus widely used to handle problems which contain imprecision. Because of this property, many multicriteria decision making techniques have been extended by using fuzzy sets. However, in cases where more than one sources of vagueness exist, classical fuzzy sets may have some shortcoming and thus new generalizations of fuzzy sets are proposed in the literature such as Type-2 fuzzy sets, intuitionistic fuzzy sets, fuzzy multisets and hesitant fuzzy sets (Rodriguez et al. 2012). In this chapter, two of these generalizations; hesitant fuzzy sets (HFS) and interval type-2 fuzzy sets are integrated to maintain a methodology for renewable energy resources evaluation. For situations where a set of values are possible for membership of a single element HFSs can be used for modeling (Torra, 2010) and in order to better handle uncertainties and vagueness in linguistic variables, interval type-2 fuzzy set (Zadeh, 1975) are used.

In this chapter, renewable energy resources are evaluated by using interval type-2 fuzzy sets and hesitant fuzzy sets. An integrated methodology is introduced and applied to the selection problem of renewable energy alternatives. The originality of the paper comes from integrating the two new methods and applies it into a MCDM problem in energy sector. The aim of the introduced methodology is to provide a multicriteria evaluation using both continuous and discrete fuzzy sets. The methodology does not force decision makers to use either continuous or discrete fuzzy sets. Interval type-2 fuzzy AHP lets the decision maker to compare the criteria using pairwise comparison matrices by continuous fuzzy sets, and determine the weights of criteria; whereas using hesitant fuzzy TOPSIS the alternatives are evaluated using discrete fuzzy sets while enabling us to collect and handle multiple scores for an alternative under a sub-criterion.

The rest of the paper is organized as follows: first renewable energy alternatives are introduced, with a brief literature review. Next, the proposed method is explained, starting from the preliminaries of interval type-2 fuzzy sets and hesitant fuzzy sets, the steps of the methodology are given in detail. The decision model, criteria and renewable energy alternatives are represented in the next section. In the application section, the renewable energy evaluation methodology is applied and the sample calculations are given. Finally, future studies and conclusions are presented.

**RENEWABLE ENERGY ALTERNATIVES**

Renewable energy is a kind of energy resource that is naturally regenerated over a short time scale and derived directly or indirectly from the sun or from other natural movements and mechanisms of the environment. In the following we briefly define the renewable energy alternatives which we take into consideration in this paper.

**Hydropower (A1)**

Hydropower energy is obtained by allowing water to fall on a turbine to turn a shaft. Electricity is produced from the kinetic energy of falling water. The water in rivers and streams can be captured and turned into
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