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A Novel Mixed Integer Programming Formulation for Selecting the Best Renewable Energies to Invest:
A Fuzzy Goal Programming Approach

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ABSTRACT

The governments seeking to invest renewable energies for electrifying far spots and/or isolated islands are always confronted with the problem of selecting the best energy (portfolio of energies) technology. To reach the optimum decision, they must take into account a variety of criteria including technical, economic, environmental and social aspects at the same time. Therefore, the main objective of this study is to address the mentioned concern by developing a multi objective mixed integer programming formulation that not only takes into account the above criteria with a focus on tax, depreciation costs and time value of money, but also optimizes a set of objective functions simultaneously. Furthermore, to model the intrinsic uncertainty of some parameters like demand and budget, a fuzzy goal programming approach is applied. In order to demonstrate the applicability of the model, a numerical example, based on the data obtained from the literature, is developed. The results indicate that, for the given conditions, hydro and PV are superior to their counterparts.

KEYWORDS

Decentralized Energy Planning, Fuzzy Goal Programming, Mixed Integer Programming, Multi Objective Optimization, Renewable Energy

1. INTRODUCTION

Energy is recognized as one of the most essential items for economic growth, human and country development. The growth of a country, encompassing all sectors of the economy and all sections of society, depends on meeting its energy requirements sufficiently (Hiremath, et al., 2011; Hiremath, et al., 2009). Although fossil fuel availability is decreasing, its demand and price and environmental concerns are growing. So identifying a sustainable energy source seems necessary (Acharya et al., 2014). In other hand, the current pattern of energy generation, which is mainly focused on fossil fuels and centralized electricity, ignores energy requirements of the isolated areas such as rural area and islands. Thus, there is a need for another approach - Decentralized energy planning (DEP) - in the interest of efficient utilization of resources. DEP is one of the options to meet the rural, isolated islands and small scale energy needs in a reliable, inexpensive, and environmentally sustainable manner (Hiremath, et al., 2011; Tsoutsos, et al., 2009). By the way, meeting the energy demand of

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fossil fuels has most important consequences around the world such as greenhouse gases like CO_2 and NO_2 emission and pollution of air, and land and water. In recent years, from an environmental point of view, the renewable energy resources are being looked as unlimited, environment friendly and sustainable sources (Kanase-Patil et al., 2010). Renewable energy is the energy caused from natural resources such as wind, tides, sunlight, rain and geothermal heat which are renewable (Kahraman & Kaya, 2010). Renewable energy is caused from natural resources such as wind, tides, sunlight, rain and geothermal heat which don't have damage to the environment (Kahraman & Kaya, 2010).

The other reason for usage of renewable energy is Climate change and global warming which is one of the most serious issues in the world today. Consequently, greenhouse gas emissions and energy generation cost are vital factor in energy planning wherever (Hessami et al., 2010), so to avoid the occurrence of this problem, the necessity of using renewable energy becomes clear.

According to the importance of investment in renewable energy and cost of these resources, different economic criteria are used in this field such as initial cost, operating and maintenance cost, fuel cost and salvages value. These criteria have different importance due to time value of money. To invest money in a project, it is necessary to compare various investment alternatives; because investment available money at the present time is worthy more than the same amount in the future. Thus, knowing worth of cash flow in present time - namely net present value- is important. There are a few researches that considered Net Present value and this paper focuses on it.

Also, another reason for choosing renewable energy is the attention of it to energy needs of the isolated areas. One of the most important criteria in isolated island is land usage and it is considered in our model (Kahraman & Kaya, 2010; Kahraman et al., 2009).

With considering the limitations mentioned, in this paper, with considering importance of DEP and renewable energy, renewable energy resources are planned with taking into account different technical, economic, environmental and social criteria. Objectives of our proposed model are maximizing NPV and job creation, and also minimizing net present cost and greenhouse gas emission.

Generating energy mechanism depends on environmental and other conditions, such as different conditions and periods, demands of energy change. In this paper, budget of the project and demand are considered as uncertain parameters and applying fuzzy approach for selecting the best item and suitable year for investment. Fuzzy approach is used for making decision in uncertain situations. It uses different α-cuts for making decision.

In section 2, some related papers are summarized and in section 3 the problem is formulate by Mixed Integer Programming. Then in section 4, fuzzy approach is explained. Section 5 gives computational results followed by conclusions in the sixth section.

2. LITERATURE REVIEW

Criteria for selecting proper renewable energy resource are most important part of energy planning problems. The literature review by Wang et al. (2009) on the application of the multi-criteria decision-making (MCDM) techniques to the energy planning shows that evaluating criteria for alternative energy sources can be grouped into four main aspects: technical, economic, environmental and social criteria, which are summarized in Table 1.

According to conflicting objectives in energy planning most studies consider multiple objectives and use various methods for selecting best resources. One useful method for solving multi objective problems is goal programming. Goal programming minimizes deviation from the goals. Kazemi & Rabbani (2013) considered both demand and supply sides in decentralized energy planning decision and applied goal programming to solve the problem. San Cristóbal (2012) studied the capacity expansion planning problem of the renewable energy industry. He developed a goal programming model in order to locate five renewable energy plants for electric generation in five places. Hiremath et al., (2009, 2010, 2011) in some researches presented a DEP model with multiple goals and limitations which are solved by goal programming.

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