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Energy project performance evaluation with sustainability perspective

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ABSTRACT

Energy is a means of economic development by raising living standards and reducing poverty. Electricity production is a vital process for households, industries and commercial activities. No two power plants are alike; they may vary in technology, size, cost, environmental aspects etc., so that evaluations shall be made on a project basis, rather than technologies. Evaluation of the best energy project among many alternatives is a complex problem which cannot be simplified to economic feasibility only, requiring investors to also consider environmental and social circumstances. This paper proposes a novel method with a sustainability perspective for better selecting concretely defined energy projects. This method is based on two multi-criteria decision making ('MCDM') techniques; AHP for determining the importance weights of evaluation criteria and VIKOR for ranking energy project alternatives. The work differentiates itself in its emphasis to analyze actual projects instead of generic energy technologies, its consideration of similar project scales, and the use of Group Decision Making ('GDM') for aggregating expert opinions. The applicability of the method is demonstrated on a case study from Turkey, where one thermal power and three renewable energy projects are compared and ranked analytically.

1. Introduction

Global economy is in need of increasing amounts of energy to sustain its economic growth. Energy is not only a means of economic development; it is also a vital component for raising living standards and reducing poverty as 1.1 billion people still do not have access to electricity [1]. Despite the need for more power generation, in particular in developing countries, today's trends in energy generation are not sustainable. As earth's population and economy grow, the demand for electricity and associated pressures on the world's ecosystems and societies increase as well. Lack of energy is closely related with the development agenda, job creation, business development and economic growth. Therefore, in today's world energy cannot be thought independent from its sustainability dimensions. National policies and international agenda also increasingly support and promote low-carbon energy options, not only out of purely environmental concerns, but also as a result of supply security issues and more volatile oil and gas prices. By 2040, renewable energy sources are expected to reach a share of 50% in the European Union, around 30% in China and Japan, and above 25% in the United States and India, while coal will account for less than 15% of electricity supply outside of Asia [2]. The usual approach for energy production so far is based on technical feasibility and economic viability, with an emerging third criterion, environmental impacts [3]. Recent developments suggest that employment and community-related aspects cannot be ignored either. Considering the negative externalities of energy generation activities, sustainability of energy projects is increasingly gaining importance [4].

As a developing country, Turkey also faces most of these challenges in its transformation of energy generation. It is the 17th largest economy in the world and 6th in Europe with a GDP exceeding USD $798 billion as of 2014 [5], and is expected to undergo a fast medium to long-term growth in energy demand, fueled by its young and urbanizing population and relatively low energy use per capita. Public policies in Turkey prioritize energy investments to ensure sufficient energy supply to its expanding economy. Turkey has liberalized its electricity market after 2001 and in the passing 15 years, thousands of large and small scale energy projects are taken into operation by independent power producers. Despite these developments, Turkey does not only struggle to meet a continuously increasing domestic energy demand at an affordable cost, it is also subject to growing public criticism for social and environmental concerns related with

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energy generation projects. Greenhouse gas emissions from energy use, for instance, have more than doubled since 1990 and are expected to rise over the coming decades [6]. This makes Turkey a good subject for assessing the performance of energy generation projects from a sustainability point of view. Recent energy projects in Turkey do not only include large scale coal and natural gas fired thermal power plants, but also a large number of renewable energy projects, mostly hydropower and wind farms, as well as solar photovoltaic, biogas and geothermal power plants to a lesser extent [7]. This is not only due to legal incentives to renewables, but also due to abundance of natural resources and a buoyant business environment willing to invest. Considering differences in economic development and environmental sensitivity across the country, selecting the most suitable energy generation project is a standalone challenge.

Identifying the most appropriate energy project can minimize environmental burden and resource use, while at the same time contributing to local economy, employment and technology transfer [8]. Similarly, a poorly decided energy generation project can lead to stakeholder reaction, ecologic damage and poor financial returns, beside others. Therefore, effective project selection is a primary concern for energy companies and financing institutions, who consider several potential energy projects at the same time, among which one or more will be selected and constructed.

Assessments limited to economic aspects only do no longer hold their former strength and applicability. In addition to the public and NGOs, regulators and financiers are increasingly scrutinizing social and environmental impacts of energy projects [9–11]. Therefore, deciding on a particular energy project is not a purely economic exercise anymore. New energy project assessment methods are needed that are not only qualitative, but also that make use of analytical techniques for integrating social and environmental decision criteria into decision support systems [12–14]. From an energy investor's point of view, the usual question to answer is not the national or regional development agenda, or the assessment of a "best technology" for a certain setting, or the best energy policy for environmental protection. Private businesses that plan to implement a power generation project usually consider the economic feasibility and financial viability of a project at the first place. In addition, they want to make sure that the project under review will be able to receive all necessary legal permits and will at least not create negative environmental or social impacts which could lead to delays, operational challenges, local complications or unforeseen costs.

Under these circumstances, this paper aims to propose a performance assessment model for energy generation projects as a decision support tool for investors and to demonstrate its usefulness on a case study. It has a sustainability perspective to effectively deal with different aspects of these projects simultaneously and to evaluate specific energy generation projects, rather than technologies. The overall aim is the development and application of a well-balanced, robust and effective method to assess and compare concretely defined energy generation projects.

The proposed model is based on two analytical techniques; Analytical Hierarchy Process ('AHP') and VIKOR (Vise Kriterijumska Optimizacija Kompromisno Resenje). Group Decision Making ('GDM') approach is used additionally for aggregating experts' opinions. This paper sees sustainability aspects of energy generation projects as a multi-criteria decision making ('MCDM') problem. The model differentiates itself from the literature by proposing unique energy project assessment criteria for energy investors. The originality of the paper also comes from its integration of AHP and VIKOR for energy project selection for the first time in literature by distinguishing energy generation projects from generic technologies. The paper furthermore presents a real case study, which compares a pool of energy projects consisting of renewables and fossil fuel-run power plants in Turkey with similar installed capacities for a better perspective. Considering that numerous energy planning models are proposed for developed countries [15], this paper aims to present a case study perspective from a developing country, where many new power plants are being planned and built. The results aim to guide business managers, researchers and other stakeholders to easily forecast projects' overall performance and decide accordingly.

The structure of the paper is as follows. In the next section, a brief literature review will be provided on energy project assessment with sustainability perspective. Subsequently, the proposed evaluation framework, along with the techniques used will be presented. In Section 4, a case study will be described to demonstrate the model's usability. Finally, the last section contains managerial implications and concluding remarks.

2. Energy project selection

Energy is today one of the most critical inputs for economies and people's lives. It gains importance parallel to electrification, industrialization and urbanization in less developed geographies [16]. Addition of new electricity production capacity frequently implies environmental pollution, hazardous emissions and social complexities, all of which may have direct or indirect economic reflections in return. Many energy projects face related difficulties, such as construction delays, economic unprofitability, stakeholder reactions, ecologic harms etc. To better manage these risks, energy projects need to be evaluated with structured approaches that do not omit sustainability dimensions.

There is a wide range of analytical methods to compare and rank energy technologies with a sustainability perspective in literature, and MCDM is one of them [12,17,18]. A limited number of these papers deal with specific energy projects, while many others focus on renewables, national energy policies, optimization of energy mix or comparison of energy technologies. A short literature review on recent publications is provided below.

MCDM is widely used for energy projects. In one example, Onar et al. [19] focused on the evaluation of wind energy investments and selected the most appropriate wind energy technology with fuzzy MCDM techniques to help investors. Chaaban et al. [20] evaluated the economic impacts of emission reductions achieved by power plants. It compared three alternatives and took account for the environmental damages related with emissions and uncertainties. Garg et al. [21] studied different thermal power plant alternatives with TOPSIS, another MCDM technique. Chatzimouratidis and Pilavachi [22] evaluated 10 different energy generation technologies with regards to five environmental criteria. The same authors [23] studied the environmental impacts of ten different power plants on the living standard by using AHP. In another study [24], they discussed power plants in terms of technological, economic and sustainability criteria again with the help of AHP and found out that renewables fare better than thermal power plants in general. Kowalski et al. [25] determined the most suitable sustainable energy technology by making use of an MCDM technique and found out that natural gas is the best fuel type. Pilavachi et al. [26] analyzed 9 power plant types fueled with natural gas or hydrogen. Using AHP with 7 criteria, they concluded that natural gas combined cycle plants perform better overall. Lee et al. [27] also used AHP to develop a new MCDM model to select a suitable wind farm project. Iniyan and Sumathy [28] presented an optimization model for energy options that minimizes the cost/efficiency ratio, while Suganthi and Williams [29] developed a model to determine the optimum allocation of renewable energy technologies to meet commercial energy needs. Burton and Hubacek [30] addressed a