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Decision making in renewable energy investments: A review

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ABSTRACT

One of the problems facing researchers in the application of renewable energy systems is that the evaluation of the sustainability is extremely perplex. Decision making in energy projects requires consideration of technical, economic, environmental and social impacts and is often complicated. This paper presents a review of the current state of the art in decision support methods applied to renewable and sustainable energy throughout the literature in the field of energy planning. The selected papers were classified by their year of publication, decision making technique, energy type, the criteria used, geographic distribution and the application areas.

Contents

1. Introduction

Energy is central to achieving the interrelated goals of modern societies: to meet human needs for heating, cooling, lighting, mobility and for running a large diversity of appliances, as well as to supply power and heat to production systems. Until the outbreak of the energy crisis, meeting these needs was a routine problem whose solution was principally a matter of money and technology availability. At these times, per capita energy consumption was a safe index of a nation's prosperity, while energy planning was aiming at supplying the energy required at the right time and in the least costly way [1]. The energy system has been the subject of substantial discussion over the course of the last 40

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years or so, but each time the discussion intensified, it was for a different reason. First, there was an oil crisis and everyone was concerned about energy security, “peak oil” and high oil prices, later the focus shifted toward climate change, with the energy system being the largest contributor of anthropogenic GHG emissions. Various alternatives have been considered: renewable energy, so called carbon capture and storage, energy demand reduction. Experiments with reality are usually very costly and could lead to undesired consequences. It is for this reason that mathematical models have been employed to help understand the functioning of the energy system, make justified decisions about its development and choosing the best technologies for combination in a particular region, or design a strategy for CO_2 emissions reduction of 80% over the course of the following 40 years [2].

As mentioned in Huang et al. [3], decision analysis (DA) was first applied to study problems in oil and gas exploration in the 1960s and its application was subsequently extended from industry to the public sector. During the 1970s, energy planning efforts were directed primarily towards energy models aimed at exploring the energy-economy relationships established in the energy sector. The main objectives followed were to accurately estimate future energy demand. A single criteria approach aimed at identifying the most efficient supply options at a low cost was popular [4,5]. In the 1980s, growing environmental awareness has slightly modified the above decision framework [6]. The need to incorporate environmental and social considerations in energy planning resulted in the increasing use of multicriteria approaches [7]. The 1991 study by Corner and Kirkwood [8] lists 86 DA studies that appeared in operations research and related journals from 1970 to 1989. They found that DA was very suitable to address strategic or policy decisions full of uncertainties and multiple conflicting criteria. In a more recent study, Keefer et al. [9] surveyed 85 articles appearing in 1990–2001 and found that the use of DA for strategic and tactical decisions was growing [10].

Given that the energy sector and energy planning in particular affects the interests and resources of multiple actors, it is socially not acceptable to suggest (or even implement) a policy alternative without taking into account the interests and preferences of the (multiple) affected factors [11]. Different and numerous groups of actors get involved in the process, each group brings along different criteria and point of view, which must be resolved within a framework of understanding and mutual compromise (concessions) [12]. The actors include those groups of individuals, institutions and administration authorities such as local authorities and communities, potential investors, academic institutions, environmental groups, governments that through their priorities and evaluation systems, have interests at stake and directly or indirectly influence the decision-making process [13].

Sustainable development means the satisfaction of present needs without compromising the ability of future generations to meet their own needs [14]. A sustainable energy sector has a balance of energy production and consumption and has, no, or minimal, negative impact on the environment (within the environmental tolerance limits), but gives the opportunity to a country to employ its social and economic activities [15].

The exploitation of renewable energy sources (RES) has gained a vast interest during the last years. Renewable energy (RE) is the energy generated from natural resources such as sunlight, wind, rain, biomass, tides and geothermal heat. RES have to overcome environmental, socio-economic, technical and institutional barriers. The complex issues of renewables render the choice between different exploitation proposals a complicated task.

1.1. A brief overview of the study

The goal of this paper is to review the recent literature in order to investigate the trends in the assessment of RES investments. The study is based on representative sample of a literature review of energy planning papers and may concern researchers and potential users of the examined methods. The current challenge was to limit the number of papers for the analysis to a manageable size but still objectively represent the state of the applications. The reader has the opportunity to be informed throughout the years for the trends in methods and application areas. It is useful to understand the reasons of these trends, in order to improve the effectiveness of applications in the future and for a candidate project which type of approach might be suitable, and where similar applications might be found.

In the sections that follow, we shall first refer to the most frequently used decision support methods applied to renewable energy problems. Then, we classify a total of 183 studies published from 1983–2014. We present the main features observed and report on new findings.

2. Decision support methods applied to renewable energy sources

The most frequently used approaches to the modelling of the energy system have been: life cycle assessment (LCA), cost benefit analysis (CBA) and multicriteria decision aid (MCDA) [2].

2.1. Life Cycle Analysis-LCA

Life Cycle Analysis (LCA) is a process to analyse and assess the environmental impacts of a product, process or activity over its whole life cycle. LCA identifies and quantifies energy and materials used and wastes released to the environment and assesses the impact of those inputs and outputs searching for environmental improvements. LCA considers the entire life cycle of the product: extracting and processing raw materials, manufacturing, transportation and distribution, use, re-use, maintenance, recycling and final disposal [16].

An LCA study involves data collection and calculation to quantify relevant inputs and outputs or the environmental load of a product system [17]. Using a LCA methodology, environmental performance indicators, including energy intensity, energy payback time (EPBT), can be determined for energy technologies. Biomass, photovoltaic (PV), and wind energy are the Renewable Energy Technologies (RETs) for which most of the LCA work has been carried out in order to assess their environmental performance for electricity generation. LCA analysis is conducted from different perspectives for electricity generation from RETs [18]:

→ LCA for determination of the environmental performance: A number of studies have been carried out to determine the lifecycle environmental performance of RETs.
→ LCA for analyzing the factors of the environmental performance. The lifetime, power ratings, load factor, type and maturity of technology, and country of manufacture influence the energy intensity of energy technologies.
→ Scenario analysis through LCA. There are some LCA studies that not only assesse the environmental performance of RETs but also include alternative energy efficiency scenarios into the lifecycle boundary in order to reduce the lifecycle environmental burden.
→ LCA for comparative analysis. LCAs of different types of RETs have been carried out in order to compare their performances.