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Exploring tapping potential of solar energy: Prioritization of Indian states

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ABSTRACT

Present study is among the first attempts to prioritize the prominent Indian states for better utilization of available solar resources. In this context, potentiality indices are performed on the basis of six prime factors that influence the effective utilization of solar energy and ranking is done accordingly. Firstly, in order to determine the weightage and hierarchy of the evaluation parameters modified digital logic (MDL) approach is employed. Availability of solar radiation is found to be the most influential parameter. Thereafter, fuzzy-analytical hierarchy process (AHP) is used for determination of the potentiality index and the corresponding ranking of different states. The ranks thus obtained are compared to current installed capacity ranks. It is found that a few states despite of high potential for the exploitation of solar energy are not getting proper attention by their respective governments. In order to promote the solar energy exploitation in such states it becomes vital to identify the vital parameters that may lead to the improvement in the current ranking. In this direction, sensitivity analysis is performed to determine the percentage change in distinct parameters which is required for the upgradation in the ranking. Such studies are capable to make a paradigm shift in technology utilization and formulation of energy policies as the proposed approach provides a concrete layout for re-evaluation of current policies as well as formulation of newer ones.

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1. Introduction

Energy crisis and green planet initiative are forcing governments, scientists, policy makers and associated experts to reassess their outlook towards sustainable green solutions under techno-socio-economic constraints. This has to happen in two ways-either to go for novel solutions which are off-course pretty time consuming or to work on effective utilization of available assets. One of such assets is renewable resources of energy. Though these are available in abundance but in order to satisfy current energy demands it is a must to have a careful cognizance for their effective utilization. In India, these are primarily classified as wind, hydro and solar. Wind and hydro resources of renewable energy are undoubtedly the most explored ones besides the various serious issues associated to them [1]. Wind energy resources are clean and environment friendly but suffers issues of noise pollution, negative environment impact, effect on biosphere and fluctuating outputs [2]. Concurrently, exploitation of hydro energy have issues of time and huge investment costs of dams [3]. Moreover, their maintenance, rehabilitation and demolition are reported among the top problems in the scientific world [4]. On the other hand closeness to the equator provides much favorable conditions for efficient exploitation of solar energy in India [5].

Indian continent receives nearly 3000 h of solar radiation every year. This amount of solar radiation is equivalent to 500 trillion kWh of energy [6]. This clearly indicates that solar projects are the best solution to meet the energy demands in Indian market. It is to be noted that these projects are quite bulky and require huge amount of investments. Hence, the knowledge of technical factors, social interests, financial aspects and governments' perspective are prerequisite. Moreover, it is essential to have consistent invigilation to resolve the unforeseen issues for effective utilization of solar resources. Interestingly, the current installed capacity of solar energy grids in India has recently increased to 2208.36 MW [7] and is expected to further rise by 20,000 MW till 2022 [8]. Table 1 highlights the current state-wise installed solar capacity and the corresponding ranks based on it [9]. However, this ranking is likely to vary with change in current installed capacity. Such variation will cause huge fluctuations in financial distribution/fund allocation by the central government. This further may require an immediate re-evaluation of current policies or formulation of the newer ones. Such domains are quite fragile and involve advanced statistical analysis. Present study comes with such an approach for prioritization of Indian states for effective utilization of available solar resources. This study aims to 1.) Determine techno-socio-economic criteria that affects the exploitation of solar energy in India; 2.) Predict weightage and hierarchy among these parameters; 3.) Calculate potentiality index (PI) and rank Indian states as per the potentiality index; 4.) Compare current (based on installed capacity) and predicted ranking; and finally 5.) Suggest the crucial parameters that are important for improvement in the current ranking of the states with larger potential in contrast to the current installed capacity/ranking.

Table 1
State wise installed solar capacity and their corresponding ranks (based on installed capacity).

States	Capacity (MW)	Ranking
Gujarat	860.40	1
Rajasthan	666.75	2
Maharashtra	237.25	3
Madhya Pradesh	195.32	4
Andhra Pradesh	92.90	5
Tamil Nadu	31.82	6
Karnataka	31.00	7
Uttar Pradesh	17.40	8
Jharkhand	16.00	9
Kerala	0.59	10
Jammu and Kashmir	0.31	11

2. Methods

Such problems can be effectively dealt with multiple attribute decision making (MADM) [10]. These methods include Modified Digital Logic (MDL), Analytic Hierarchy Process (AHP) [11], graph theory and matrix approach (GTMA) [12], TOPSIS [13], VIKOR [14] and many others. These tools have been applied to an ample spectrum of applications such as site selection [15,16], materials selection [17,18], supply chain management [19], scientific decisions [20] and engineering problems [21]. We have been dedicatedly working on these techniques [10,13,14,22–26] and attained a critical understanding for implementation of these techniques in terms of working principles and their pros and cons. Among these, GTMA is a logical and systematic approach (based on advanced graph theory) but requires complex calculations [12,28] while TOPSIS and VIKOR are quite simple and easy to implement. TOPSIS works on Euclidian distances and requires nonlinear normalization while VIKOR works on linear normalizations and is based on regret analysis. Both the methods provides nearly similar results. However, both the methods have a time consuming and complicated sensitivity analysis procedure and are therefore not suitable for the present study. Contemporary, AHP is a simpler and effective tool for dealing with complex decision making problems. The basic principle of AHP is to simplify a complex decision problem by braking down the problem into hierarchy of criteria [29]. Therefore, in limelight of the objectives of the present study and understanding gained by us in past; present study utilizes fuzzy-AHP in combination with MDL weights of the evaluation parameters to predict the potentiality index and corresponding ranking of Indian states [30]. Henceforth, the ranking is compared to the current installed capacity ranking and an attempt is made to quantitatively understand the difference between the two. The reasons behind any deviation in the current installed capacity ranking from the predicted one helps in depicting the areas to be focused on for the improvement in present ranking and so as to have effective utilization. In this context, sensitivity analysis is performed to figure out the percentage change in parameters (potentiality improvement index: PII) that may lead to improvement in the present ranking of the lacking states. Thus, the ranking/potentiality improvement index (PII) obtained can be very helpful to the states as well as central government in formulating newer policies and