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Evaluating the enablers in solar power developments in the current scenario using fuzzy DEMATEL: An Indian perspective

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ABSTRACT

Determining solar power initiatives and developments for a country as large as India is difficult due to the involvement of different enablers. The decisions of these enablers will influence the formulation of strategies to encourage solar power development in India. The present research work critically analyzes Indian solar power developments to recognize and to evaluate key enablers that will encourage greater usage in India's current scenario. A literature review that explores the Indian solar power sector is included, with a focus on need potential, and an examination of the key enablers. This work identifies sixteen solar power enablers based on relevant literature and experts' inputs. To evaluate and to categorize the recognized solar power development key enablers, a fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) based methodology is utilized. The fuzzy DEMATEL approach is useful in dealing with the inherent ambiguity involved in studying interrelationships among the evaluated enablers. Research findings suggest that Initiatives taken at the state level (E7) and Power sector reforms (E12) have significant influence in adopting and encouraging India's solar power development. In this research, the enablers' causal relationships and their interactions are examined, and the findings are useful to encourage solar power development initiatives and decisions. This work will help policymakers formulate decisions to initiate and encourage solar power developments in India.

Contents

Abbreviations: IEA, International Energy Agency; PV, Photovoltaic; CASE, Commission for Additional Sources of Energy; DNES, Department of Non-conventional Energy Sources; IREDA, Indian Renewable Energy Development Agency; MNES, Ministry of Non-conventional Energy Sources; BHEL, Bharat Heavy Electricals Limited; RGGVY, Rajiv Gandhi Grameen Vidyutikaran Yojana; CEA, Central Electricity Authority; MoP, Ministry of Power; CERC, Central Electricity Regulatory Commission; SERC, State Electricity Regulatory Commission; RPO, Renewable Purchase Obligations; MNRE, Ministry of New and Renewable Energy; JNNSM, Jawaharlal Nehru National Solar Mission; NAPCC, National Action Plan for Climate Change; CSP, Concentrated Solar Power; PVT, PhotoVoltaic Thermal; a-Si, Amorphous Silicon; ASSCP, Amorphous Silicon Solar Cell Plant; LFC, Linear Fresnel collector; MWe, Megawatt electric; GDP, Gross Domestic Product; REC, Renewable Energy Certificate; NTP, Notified Tariff Policy; PACE, Advance Clean Energy; MoU, Memorandums of understandings; ASE, Angewandte Solar energies; FDI, Foreign Direct Investment; VVNL, Vidyut Vyapar Nigam Limited; SEC, Solar Energy Center; DEMATEL, Decision Making Trial and Evaluation Laboratory; TrFN, Trapezoidal fuzzy number

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1. Introduction

Energy is an important requirement for the development of societies, and per capita consumption of energy is one factor of economic growth for a country. Traditional sources of energy such as coal, oil, and natural gas are being depleted rapidly. Moreover, these sources of energy are major contributors to environmental pollution and global warming. The current energy crisis and environmental worries can be minimized by increasing the use of renewable energy sources to their full potential [1]. The goal of long-term energy security and environmental sustainability can be achieved only by the maximum use of efficient and cleaner sources of energy [2].

India faces a soaring energy demand from its growing population and rapidly expanding economy. According to International Energy Agency (IEA) predictions, after 2020, India will become the single-largest country for global oil demand [3]. India's economy has grown at an annual growth rate of 10% over the last decade and is expected to grow by another 11% by 2020 [4]. To meet the increasing demands of a burgeoning population and to keep pace with economic growth, India requires massive additions to its capacity to generate electricity. At the same time, the Indian government is under tremendous pressure at various international levels to take initiatives to conserve resources and to mitigate climate related problems [5,6]. Further, there are various problems related to resources conservation and energy management in the Indian context. Some of those issues are:

- Due to the rise in living standards and the increase in industrial activities in India, the demand for electrical energy in the year 2016–17 is anticipated to be 1392 TWh with a peak electric demand of 218 GW. Similarly, the demand for electrical energy in the year 2021–22 is anticipated to be 1915 TWh with a peak electric demand of 298 GW [6].
- The Indian power sector is facing huge transmission and distribution losses. Although government claims these losses to be 23% of generated electricity, researchers and independent agencies have estimated them to be more than 50% [7].
- With a population of more than 1.27 billion, India is second-most populous country [11]. Almost 70% of India's population lives in rural areas where reliable and assured energy is not available. More than 44.2% (84 million households) still have no access to electricity [8].
- In addition to this, there is a projected gap of 6.7 percent between India's energy supply and demand.

An important reason behind the country's shortage of electricity is its overdependence on thermal energy for electricity generation. Around 68%of India's total installed capacity of energy comes from thermal units [3]. A summary of problems related to India's power sector has already been provided [9]. The need to cater to the ever-growing energy demand and environmental pollution in the country has led to the promotion of renewable energy sources. Some renewable sources of energy are wind energy, geothermal energy, turbine energy, and solar energy. The potential of solar energy ranks among the highest of the various renewable energy resources available in India. There are several benefits to using solar power:

- Solar power is clean, available in abundance, and is free to harness [10,11].
- Solar power has become more of a business proposition for investors in the country and it equally contributes to the development of economy, as its returns are visible three-fold (i.e., economically, socially, and environmentally) [12].
- Ecological protection, being cost-effective, employment generation, diversity in fuel supply, technology and innovation, are issues that transfer across the world [13].
- Solar energy fulfills many purposes in the industrial, agricultural, domestic, and commercial sectors of the economy [14].

Renewable energy development in India has progressed at a rapid pace, especially from 2010 [15]. While continued strong growth over the next decade is desired, there is a significant need