Energy-exergy-economic-environmental-energo-exergo-enviro-economic (7E) analysis of solar photovoltaic power plant: A case study of 7 airport sites in India

S. Sreenath a, K. Sudhakar b,c,d,*, A.F. Yusop b

a Renewable Energy and Energy Efficiency Research Cluster, College of Engineering, Universiti Malaysia Pahang, Gambang, Kuantan 26300, Pahang, Malaysia
b Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
c Centre for Automotive Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
d Energy Centre, Maulana Azad National Institute of Technology Bhopal, M.P, India

ABSTRACT
Solar PV development gained airport operators’ attention in the wake of its negligible carbon emission and onsite electricity generation. The solar PV projects in airports cater to its energy, economic and environmental needs. A comprehensive study on multi-dimensional performance aspects of the airport-based solar PV system is not presented anywhere. This study investigates the energy, exergy, economic, environmental, energoeconomic, exergoeconomic, and enviroeconomic (7E) performance of solar PV power plant proposed in the premises of 7 Indian airports. For the ease of performance comparison, an identical 5 MW solar PV system is designed for each airport location. At first, the energy generation, economic, and environmental performance are assessed with the help of RETScreen software. Then, an Excel-based mathematical model was developed to estimate exergy, energoeconomic, exergoeconomic, and enviroeconomic parameters. Satisfactory performance ratio (more than 79%) and system efficiency (more than 14%) are predicted in all the selected airport locations. The minimum and maximum values of exergy efficiency are estimated as 9.89% (Goa airport) and 12.00% (Lucknow airport), respectively. Except for Ahmedabad airport and Dehradun airport, the IRR value is less than the discount rate (10%) for the five airports, with Goa airport on the borderline (9.5%). Dehradun airport has the most favorable 7E parameters among the selected seven airports with 82.21% PR, 20.56% CUF, 15.13% exergy efficiency, 3.7 years payback, 13.30% IRR, 7.5 cents LCOE, 8060 tCO₂ avoided/ annum. In addition, it has the lowest value of exergoeconomic & energoeconomic parameter and the highest value of enviroeconomic performance among the selected locations. The application of the 7E framework is expected to provide valuable insights into the feasibility study of the solar photovoltaic system in airports.

Introduction
Airports are energy intensive in nature. A huge amount of electrical energy is needed to meet the lighting, heating, and cooling loads in a busy airport [1]. The electricity consumed in airports is typically generated from conventional sources of energy such as coal, fossil fuels, etc. This indirect carbon emission caused by the airport’s operation deviates from its sustainable goals [2]. In this regard, onsite renewable energy generation has gained the attention of many airport operators. The vast vacant spaces in airport premises have been used for the deployment of solar photovoltaic systems. In addition to the reduction in carbon emission, the use of solar energy can reduce the energy cost, provide additional revenue, supports environmental stewardship for airport operation [3,4].

Some authors elucidated the performance of the solar photovoltaic system in airports [5–7]. In a recent work, Sher et al. [8] assessed the feasibility of a 12 MWp solar PV power plant at an airport in the United Kingdom (UK) and observed the average values of energy yield, performance ratio & carbon emission reduction as 2585.74 kWh/kWp/month, 82.59% and 11,643 tons respectively. Yildiz and Yilmaz [9] proposed a 1 MW solar PV power plant for Gaziantep Airport, Turkey, and predicted the energy, economic & environmental benefits using PVsyst simulation software. The proposed power plant is expected to generate 1702.09 MWh electrical energy annually with a payback...