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A study to incorporate renewable energy technologies into the power portfolio of Karachi, Pakistan

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ABSTRACT

Karachi is facing severe power outage problems, with 3 to 8 hours of power outages every day, accounting for large economic losses. The city has a total electricity generation capacity of 2848 MW and a peak load of 2500 MW. This study estimates the potential of Solar, Wind and Biomass renewable energy options to meet part of the electrical demand in Karachi, Pakistan and further discusses the feasibility of the proposed projects. The objective is to define and evaluate a mix of these renewable energies that offsets 10% of the peak load (250 MW) of Karachi. The approach is based on the sustainability principle that a city should first attempt to meet its electrical demand using its own resources in order to increase its energy security, support the local economy, and minimize the costs and losses associated with transportation of fuel, and transmission and distribution of electricity. For the proposed mix, 2.9% and 4.4% of the peak load demand is met using Solar Photovoltaic (PV) and Parabolic Trough Collectors (PTC) respectively, 2% from wind and 0.7% from biomass. Also, the proposed mix is found feasible with PV to recover its investment costs in 5 years followed by biomass and wind in 6 years and finally PTC in 17 years. The outcomes of this analysis are significant for the concerned authorities of Pakistan responsible for installing renewable energy utilization projects within its regions.

Contents

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1. Introduction

`Karachi is the largest industrial hub of Pakistan, located at 24.86°N and 67.01°E along the coast of the Arabian Sea. The city has a population of 13 million and contributes a large share of the revenue generated in Pakistan. Currently it is facing power outage problems, with 3 to 8 hours of load shedding every day. Load shedding has already had a severe negative impact on the economic sector of the city. Destabilization of Karachi's industrial and trade activities shakes the economy of the whole country; hence a reliable and constant power supply to these sectors should be given extreme importance. Reliability can be increased by diversifying the energy mix beyond one or two fuels only and using local renewable resources.

Karachi Electric Supply Company (KESC) is responsible for providing electric power to the mega city Karachi but not only this, it is also a major contributor to the power production in Pakistan as a whole. KESC is primarily engaged in power generation, transmission and distribution to the industrial, commercial, agricultural and residential sectors of Karachi. The company has a generation capacity of 1955 MW from oil- and gas-fired power plants which are not operating at their maximum capacity due to shortages in oil and gas supplies [1]. The approximate peak load demand for power in Karachi is 2500 MW [1]. To meet this gap between supply and demand, KESC purchases power from the Water and Power Development Authority (WAPDA), the Karachi Nuclear Power Plant (KANUPP) and Independent Power Producers (IPP's) [1]. Whenever any of these electricity sources fails to deliver power due to a fuel shortage or unexpected failure, KESC has to restore load-shedding which is now a regular practice. In spite of having good renewable energy resources both in the city and the country, the share of renewable energy, e.g. solar, wind, biomass, etc., in the electricity generation mix remains very low. Also, at national level if Pakistan has to cope with its energy crises, it is imperative that renewable resources for energy should be explored. For this initiative, it is essential to start on a regional basis, with an obvious starting point being the strategic city of Karachi, which has the largest population and the most industrial activity.

Presently, there are several studies present in the literature providing an overview of renewable energy potentials in Pakistan. Asif [2] discusses the different dimensions of the energy crisis, which includes the increasing gap between supply and demand, rising energy costs, power supply security concerns, and declining oil and gas reserves. As a solution to these problems, the author assesses the renewable energy potential for Pakistan, estimating the total hydropower potential to be 42 GW and the solar resources to be 1900–2200 kW h m^{-2} of annual global irradiance, making Pakistan a rich country in terms of solar resources. Sahir et al. [3] present the practical limitations to the use of renewable energy resources considering the present scenario and future forecasts of the energy mix of Pakistan. They demonstrate that solar, wind and biomass will play a significant role in the future for energy generation in Pakistan, but these resources cannot be considered as direct substitutes for conventional energy sources.

Mirza et al. [4] discuss the status of solar energy use in Pakistan, stating the need for R&D organizations to promote solar energy technologies. They also identify that the current infrastructure does not have the capability to support solar energy technologies in Pakistan [4]. In another study by Mirza et al. [5], the past, present and future utilization of wind energy in Pakistan is discussed. Large wind resources are identified along the 1000 km coast in the south of the country (region where Karachi is situated) and in high mountains of northern Pakistan. Barriers to the development of wind energy technologies are also discussed, clarifying the need for dedicated efforts from policy makers to utilize these resources effectively [5]. Bhutto et al., [6] highlight issues and challenges in the efficient and effective utilization of biomass as an energy source in Pakistan. They not only focus on electricity production from biomass but also its use as an industrial and domestic fuel. They identify areas which require attention from local government for establishing and improving biomass energy production and delivery systems. Zuberi et al. [7] concluded that biomass resources in Pakistan are capable of contributing 42% to the power portfolio of the country.

All of the aforementioned studies have focused on the overall scenario of renewable energy resource potential and challenges for its development at the national level. Some studies can also be found in literature focusing on potentials and challenges at regional level especially for the economic hub of the country, Karachi. Sajjad et al. [8] analyzed the maximum data available for Karachi regarding urbanization, population and vehicles growth, industrialization, energy consumption and CO_2 emissions. Their results show that from 1947 to 2008, urban population and urban area has increased 1500%. Their analysis further reveals that during 1980–2007, consumption of oil and gasoline, natural gas and coal increased 219%, 365% and 287%, respectively. The emission of CO_2 jumped from 39 million metric tons in 1980 to 151 million metric tons in 2007. Their study recommends switching to alternative energy resources. Aman et al. [9] investigated the possible wind energy potential and challenges to meet the power shortages in Karachi, which currently stands at 328 MW. They showed that 1678 MW h of energy could be saved if 50% of residential consumers is equipped with small wind turbines.

The motivation for this research comes from the ongoing energy crises, economic instability, social issues and increased pollution levels currently faced by Karachi. The objective of this study is to offset 10% of the peak demand (250 MW) of Karachi using solar, wind and biomass resources. For this purpose, resource and economic models are developed and applied to estimate the electricity generation potentials for each of the three resources. The said approach is primarily based on the sustainability principle that the city should meet its electricity demand by using its own energy resources. Hence the resource estimates made for solar, wind and biomass energy in this study are all within the close perimeters of the city. This work builds on the studies performed earlier as follows:

1. Previous research studied decreasing the energy deficit for all of Pakistan by employing renewable energy resources. In contrast, this study addresses the electricity supply demand gap specifically for Karachi and presents a sustainable solution for it.
2. Previous research has identified that a hallmark of sustainable development is to try to solve problems of specific areas and cities using local resources first. As a first step the present work