Masters Desertion Showcase
Year 2024

Department: Mechanical Engineering Programme: Masters in Engineering Specialization: Energy Systems	
1	**Title of the Thesis** Evaluating the effect of air pollution on daily global solar radiation prediction
2	**Abstract** (300 to 500 words) Solar radiation estimation is significantly influenced by air pollution, alongside other meteorological factors. While global solar radiation models have been developed for various locations in Pakistan, the specific impact of air pollution on solar radiation remains largely unexamined, creating a gap in understanding the influence of pollution on solar energy dynamics. Furthermore, previous studies using traditional empirical models have employed different combinations of input parameters without systematically exploring or comparing all potential combinations to identify optimal scenarios for achieving the most accurate results. This lack of systematic exploration limits our understanding of how best to predict solar radiation, particularly in urban areas like Karachi, which face significant air pollution challenges. This study aims to fill this gap by developing empirical and machine learning models to estimate global and diffuse solar radiation in Karachi, focusing on the influence of air pollution. Multi-Linear Regression (MLR) and Artificial Neural Network (ANN) models were constructed using common meteorological parameters, both excluding and including air pollution metrics ($PM_{2.5}$ and AQI). Meteorological data were sourced from the weather station at NED University of Engineering and Technology (NEDUET), and air pollution data from the US consulate. After data pre-processing, model accuracy was evaluated using statistical metrics such as normalized root mean square error (*nRMSE*), normalized mean absolute error (*nMAE*), and correlation coefficient (*R*). The results indicate that incorporating air pollution parameters enhances model performance. The optimal model for predicting the clearness index (H/H_o) included wind speed (WS), AQI, and $PM_{2.5}$, achieving *R*=0.8204. The diffuse fraction (H_d/H) was best predicted using the clearness index and other meteorological parameters, achieving *R*=0.9353. Across both H/H_o and H_d/H models, a consistent trend is observed. ANN models generally outperform MLR models, particularly when multiple parameters are included. Overall, these findings highlight the necessity of integrating both meteorological and air quality parameters to develop robust solar radiation models, particularly in arid environments.
3	**Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities" (min 500 words)** The relationship between air pollution and solar radiation has significant implications for urban sustainability, aligning closely with Sustainable Development Goal 11 (SDG 11). As cities grow and urbanization accelerates, especially in developing nations like Pakistan, urban regions face mounting challenges associated with air pollution and energy demands. Solar energy offers a viable solution to energy shortages in these areas, but the effectiveness of solar energy systems is heavily influenced by air quality. Consequently, understanding the impact of air pollution on solar radiation is essential for optimizing solar energy production and improving urban sustainability.

Urban regions, particularly in large cities like Karachi, face a dual challenge of increasing energy demands and deteriorating air quality. Air pollution, largely resulting from vehicle emissions, industrial activities, and construction, affects not only human health but also the efficiency of solar energy systems. Pollutants like particulate matter ($PM_{2.5}$) scatter sunlight, reducing the amount of solar radiation that reaches solar panels. This "solar dimming" limits the energy generation capacity of solar photovoltaic (PV) systems. The ability to predict solar radiation accurately is crucial for designing effective solar energy infrastructure that can meet urban energy needs while minimizing environmental impact.

Target 11.6.2 specifically addresses air quality as a key environmental indicator for urban areas, recognizing that improving air quality is critical for sustainable urban development. The findings from this study directly contribute to this target by providing evidence of how pollution interferes with solar energy systems, which are an increasingly important part of sustainable energy strategies in urban environments. In cities like Karachi, where energy demands are rising and pollution is rampant, understanding the influence of air pollution on solar energy systems helps urban planners and policymakers develop more accurate and effective strategies for renewable energy deployment.

By improving air quality, cities can enhance the efficiency of their solar energy systems, reducing their dependence on fossil fuels and decreasing their overall environmental impact. This aligns with Target 11.6's goal of reducing the environmental impact of urban areas by improving air quality. Moreover, the study suggests that incorporating air pollution data alongside meteorological parameters in solar energy infrastructure planning will lead to better energy efficiency, ultimately contributing to more sustainable cities. The use of Artificial Neural Network (ANN) models in this research shows that when pollution metrics are accounted for, solar radiation predictions become more accurate, leading to more reliable solar energy generation forecasts.

The implications of this research extend beyond Karachi to other urban centers facing similar challenges. For cities with high levels of pollution, the results highlight the importance of integrating air quality data into energy planning frameworks. Policymakers can use these insights to adjust solar energy policies and infrastructure, ensuring that energy production remains resilient even in polluted environments. Additionally, this contributes to SDG 11.6's broader objective of improving the quality of life in urban areas by ensuring that clean energy sources like solar power are used efficiently, thus lowering greenhouse gas emissions and reducing the overall environmental footprint of cities.

The findings of this research not only underscore the importance of addressing air pollution for improving solar energy efficiency but also emphasize the broader implications for urban sustainability and resilience. By taking actionable steps to improve air quality, cities can harness the full potential of solar energy systems, fostering a cleaner, healthier urban environment.

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