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Environmental Impact Assessments of the Renewable Energy Technologies Adaptation

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Abstract- **Using a method of multidimensional analysis, this study compares several renewable resources and technologies. Using the check-list matrix method, the environmental impacts of various renewable technologies are evaluated and compared based on their significance, impact, and duration. Based on their impact on soil, air, and water resources, solar thermal technologies and direct combustion of bio-mass resource received the highest impact scores, posing threat to the environment. However, renewable energy from run-of-river is the most promising and sustainable option, followed by wind andsolar PV with moderate of low impact scores. Based on the qualitative analysis conducted in the study, it study reports that all renewable technology options have a low to high varying significance impact on the environment and cannot be considered a comprehensive solution to Pakistan's environmental problem.**

***Index Terms*--** **Renewable Technologies Assessment, Multi-Dimensional Impact Assessment, Environmental Sustainability**

I. INTRODUCTION

Since the industrial revolution, the global energy demand has increased. Fossil fuels have played a significant role in meeting energy demands. However, the increased use of fossil fuels to meet energy demand has not only exacerbated the problem of energy security but has also exponentially increased global emissions [1–3]. Similar to other nations, Pakistan relies heavily on fossil fuels to meet its energy needs. Approximately 80% of the demand is met by conventional sources such as nonrenewable resources [4]. This accelerated supply to meet demand has negatively impacted Pakistan's environment, forcing policymakers to consider a greener alternative, such as renewable energies, to continue development while addressing environmental concerns [5].

Renewable resources are viewed as a promising option for optimally satisfying the energy demand. Renewable resources are self-renewing and emit no direct emissions during use [6]. However, renewable technologies continue to produce a significant amount of emissions throughout their lifetime, beginning with their fabrication and continuing through their commissioning and decommissioning [7]. Several nations, including Pakistan, have invested in renewable technologies to combat environmental issues. However, the utilization of renewable technologies in reducing these emissions and addressing the issue must be evaluated.

In the presented work [8–13], numerous researchers have presented the life cycle assessment of various renewable technologies. However, these studies did not provide a comprehensive comparison of all renewable technologies. In addition, no comprehensive analysis of the applicability and comparison of various renewable technologies has been presented in the context of Pakistan. This study aims to analyze the environmental impacts of renewable technologies in response to the research question, “Is the use of Renewable Energy a comprehensive solution to environmental problems?" The study evaluates the objective based on two primary variables: 1. Direct Effects of Diverse Renewable Technologies on the Environment; 2. Indirect Effects of Diverse Renewable Technologies on the Environment.

II. METHODOLOGY

In recent years, a variety of impact assessment methods have been developed to analyze different aspects of impacts based on the need. Various researchers employ various methods and techniques for environmental impact assessment [14, 15]. Multiple variables and approaches constitute the optimal approach for Environmental Impact Assessment. Among the best EIA practices, the following approaches are employed most frequently:

1. Recognizing and defining the Effect
2. Analyzing the direct and indirect effects of the proposed action
3. Determining the impact's magnitude or significance

The research employs a method of multidimensional analysis to assess the impact. The study adheres to the methodology outlinedin

Fig. 1. Environmental Impact Assessment of various renewable technologies in the context of Pakistan is conducted using an impact assessment matrix. This methodology provides an overview of the distribution and classification of the impact various renewable resources and their technologies by analyzing various variables such as time and importance. It investigates theentire life cycle of renewable resource utilization. This approach emphasizes the identification of impacts and quantification of those impacts so that they can be compared and analyzed relative to various renewable technologies.

The proposed methodology involves a combination of approaches:

1. Identification of Impact
2. Evaluation of Impact
   a. The character of impact
   b. The time duration of impact
   c. The significance of impact
3. The Quantification of Impacts
4. Comparison among the impacts score of different Renewable Technologies.

The use of this methodology provides a clear understanding of the extent of impact caused by various renewable technologies, as well as quantified results for decision-makers and policymakers to plan and implement possible solutions for the utilization of various renewable technologies in Pakistan. Based on its LCA, each technology's impact factor is evaluated. The magnitude of the impacts are rated on a scale from 0 to 5 according to the following scale: No impact, Very low impact, Acceptable impact, Moderate impact, High impact, and Very high impact, respectively.

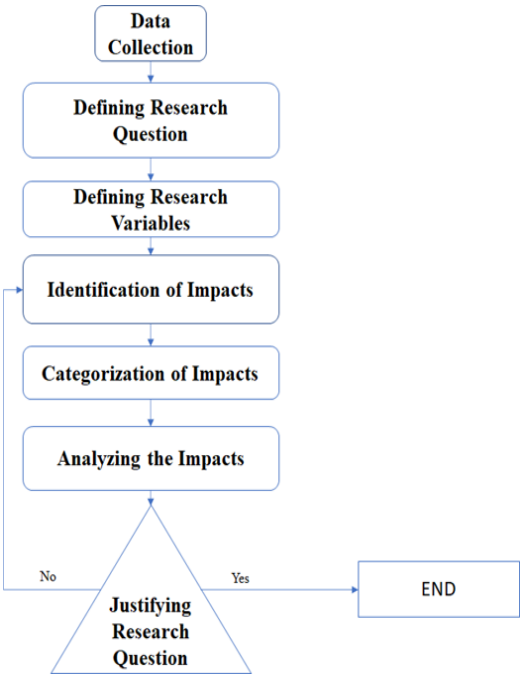

Figure 1: Methodology Flow Diagram.

III. RESULTS & DISCUSSION

For the Pakistan case study, a multidimensional checklist methodis used to analyze the environmental impact of various renewable technologies. This is primarily because the checklist method quantifies the results, which greatly assists in validating the data. It provides a comprehensive understanding of the baseline situation, as well as the quantification and comparison of the effects of various renewable technologies.

A. IMPACT OF SOLAR PV AND THERMAL TECHNOLOGIES

Solar PV technologies have a tolerable impact on ground and surface water sources; however, during the manufacturing of solar cells, a significant amount of water, approximately 0.023m3/MWh, is consumed, making the impact rating on water usage moderate [16]. Earth-extracted silicon and other metals are utilized in the manufacturing of solar PV technologies. This contributes to soil contamination, making the impact moderate. The production of solar photovoltaic (PV) systems is energy intensive and produces a substantial amount of greenhouse gases [17]. This gives solar PV technologies a high impact score in terms of greenhouse gas emissions. Solar PV technologies have a low conversion efficiency, necessitating a large deployment area to maximize energy production. This has a moderate to high impact on the diversity of flora and fauna, as well as soil erosion resulting from land use change. In the case of Pakistan, most solar panels are brought into the country, thus offsetting the impact of manufacturing. In the case of Pakistan, all major deployments of solar technologies are either on the rooftops of buildings or on marginal lands, which significantly reduces the impacts Similar to solar PV technologies, solar thermal technologies have minimal impact on the ground water supply. However, solar thermal technologies have a moderate effect on the quality of surface water and water consumption. Solar Thermal require an average of 3.07 m3/MWh of water over the lifetime of the system, as well as significantly contaminate the surface water through mixing of specialized fluids used in the technologies with the surface water or high temperature water leakage from the system [16] [18]. In addition, because thermal technology has a lower conversion efficiency, it necessitates a large land area, resulting in a significant amount of land use and landscape change, as well as an impact on soil contamination and erosion. However, solar technologies require less energy during production, resulting in lower GHG emissions than Solar PV technologies. These effects are typically transient and of local significance, and the likelihood of their occurrence is typically moderate to high.

B. IMPACT OF WIND TURBINE TECHNOLOGIES

Wind turbine technologies comparable to solar photovoltaics have minimal impact on surface and ground water resources and use less water than solar technologies [19, 20]. Moreover, wind turbine technologies require less space for implementation and have a higher energy density per area than other technologies. Due to the movement of wind turbine blades and flickering effect, wind turbine technologies have moderate to severe impacts on land scaping and the biodiversity of flora and fauna [21].

In addition, the movement of the blades results in the loss of fauna diversity, as birds and other species become entangled in the blade coverage area, resulting in a moderate impact [9].

C. IMPACT OF BIO-MASS TECHNOLOGIES

In contrast to solar and wind technologies, bio-mass technologies

have a moderate to high impact on surface and ground water and consume large quantities of water throughout their life cycle [22][23]. This is primarily due to the fact that the majority of bio- masscomes from plants and other organic sources, which require a great deal of water. Moreover, bio-mass direct combustion and gasification technologies generate a substantial amount of greenhouse gas emissions, primarily CO2, CO, NOx, and other flue gases, as well as particulate emissions, which significantly degrade air quality [22] [24]. However, they have negligible or negligible effects on land use, land scaping, and threaten the diversity of flora and fauna less than other technologies [25]. These effects are typically long-lasting, have local to regional significance, and have a greater likelihood of occurring Table I.

Table I
Impact Score Matrix of various Renewable Technologies

	Renewable Technologies						
Env. Components	Solar PV	Solar Thermal	Wind Turbine	Bio-Mass DC	Biogas	Hydro Reservoir	Hydro ROR
Surface Water	1	3	1	0	2	3	1
Ground Water	1	1	1	3	4	2	1
Water Usage	2	3	1	3	4	1	1
Soil Contamination	2	3	2	2	2	2	2
Soil Erosion	3	4	2	3	2	3	0
Air Quality	1	3	0	5	3	2	3
GHG Emission	4	2	2	5	3	2	3
Noise	0	0	3	0	0	0	0
Diversity of Flora	2	2	3	1	1	3	3
Diversity of Fauna	2	2	3	1	1	3	2
Land Use	4	5	2	2	2	5	1
Land Scaping	2	3	4	0	0	2	1
TOTAL IMPACT SCORE	**24**	**31**	**23**	**27**	**26**	**26**	**12**

D. IMPACT OF HYDRO TECHNOLOGIES

Hydro-Technologies, in contrast to Solar or Wind Technologies, have a significant impact on surface and ground water resources, particularly in the case of hydro reservoir systems [20], [26]. Due primarily to the retention of water in the reservoir, the water level in the surrounding areas rises, bringing with it soil salts and metals to the upper surface, where they mix with ground and surface water, thereby degrading their quality. However, this effect is minimal in the case of run-of-the-river technology. Another significant disadvantage of hydro-reservoir technology is

the need for large land areas for storage, which severely degrades soil quality, causes soil erosion, and results in the loss of habitat for flora and fauna. In addition, hydro technologies pose a grave threat to the diversity of flora and fauna because they alter or disrupt the natural flow channel and habitat of aquatic flora and fauna [20] [27].

E. SUITABILITY OF RENEWABLE TECHNOLOGY FOR PAKISTAN

The environmental impacts of numerous renewable technologies and resources available in Pakistan are analyzed. Among the resources evaluated, river-run hydropower received the lowest impact score of 12, followed by wind power and photovoltaics. The bio-mass conventional use of Direct combustion for space heating and other applications received the highest impact score.

Due to the fact that it does not necessitate any specialized infrastructure for implementation, river-run hydropower has the lowest impact score. Moreover, it uses the kinetic energy of moving water for energy harvesting, causing minimal environmental disruption. Wind energy, on the other hand, has a negligible impact because its production requires less energy and less space. However, it has significant sociological effects, such as the shadowing effect and noise pollution's effect on fauna diversity [28].

Direct combustion of bio-mass is the most harmful renewable technology from the perspective of Pakistan. This not only produces uncontrolled flue gases, but also causes a reduction in air quality with regional and, in some cases, transnational significance. However, solar PV and thermal systems do not have a significant impact on Pakistan's environment because the majority of environmental damage, such as greenhouse gas emissions, is produced during the manufacturing phase. Pakistan does not produce these technologies domestically, but rather imports them from other nations, thereby reducing its environmental impact on the country's mainland. These technologies' low operational emissions have a negligible effect on Pakistan's environment.

Reservoir-based hydropower is one of the largest contributors to Pakistan's electricity mix. However, these reservoirs have caused significant damage in Pakistan, particularly in the case of Mangla Dam, where an entire area was evacuated to be used as a water catchment area, disrupting the local eco system and causing environmental damage. Pakistan is an agricultural nation with major waterways flowing from the north to the south. Wind potential exists in the coastal, central, and western regions of Pakistan, whereas solar potential is widespread across Pakistan's terrain. The ice-capped mountains in the northern region of Pakistan generate a significant amount of water flow in the rivers of the region. This water flow has a tremendous potential for producing energy via river runoff. In addition, this type of utilization will necessitate low capital expenditures and cause minimal environmental damage, providing Pakistan with green energy development.

Based on the discussion in the preceding sections, renewable energy sources such as wind, solar, bio-mass, and hydro power are acknowledged as promising alternatives for reducing emissions from fossil fuels. However, a significant number of emissions, environmental impacts, and concerns are still associated with their use. On a small scale, environmental concerns and effects are less significant. However, when applied on a large scale, these impacts cause severe environmental concerns, making renewable technologies less desirable and less desirable for implementation. To achieve sustainable energy, these concerns must be addressed, and the location, type, and infrastructure development of these renewable technologies must

receive particular attention. Based on the preceding discussion, it can be concluded that Renewable technologies are not a complete solution to the environmental problems in the current context.

IV. CONCLUSION & RECOMMENDATIONS

Solar, wind, biomass, and hydropower have been demonstrated to be a superior alternative to conventional fossil fuels, resulting in a substantial decrease in emissions. However, the results demonstrate the impact significance of various renewable technologies in Pakistan, indicating that not all renewable technologies produce a sustainable outcome. Renewable technologies such as direct combustion of bio-mass and solar thermal pose a direct threat to the environment in the vicinity, resulting in a higher impact score and significance. In the context of Pakistan, technologies such as run-of-river hydropower, solar photovoltaics, and wind turbines are promising options for implementation as alternative energy sources, primarily due to their implementable areas and manageable impacts. To achieve a sustainable solution, however, a proper impact mitigation plan must be formulated and implemented. The study concludes that, based on the results' inferences, the use of renewable energy is not a complete environmental solution. To achieve a comprehensive solution to Pakistan's environmental problems, it is necessary to design and implement a fully sustainable eco-system.

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REFERENCES

[1] C. Le Quéré et al., “Global Carbon Budget 2018,” Earth Syst. Sci. Data, vol. 10, pp. 2141–2194, 2018, doi: 10.5194/essd- 2018-120.

[2] R. B. Jackson et al., “Global energy growth is outpacing decarbonization,” Environmental Research Letters, vol. 13, no. 12. Institute of Physics Publishing, p. 120401, Dec. 2018, doi: 10.1088/1748-9326/aaf303.

[3] S. Safarian, S. Sattari, R. Unnthorsson, and Z. Hamidzadeh, “Prioritization of Bioethanol Production Systems from Agricultural and Waste Agricultural Biomass Using Multi- criteria Decision Making,” Biophys. Econ. Resour. Qual., vol. 4, no. 1, pp. 1–16, Mar. 2019, doi: 10.1007/s41247-019-0052- 0.

[4] R. Komal and F. Abbas, “Linking financial development, economic growth and energy consumption in Pakistan,” Renew. Sustain. Energy Rev., vol. 44, pp. 211–220, 2015.

[5] R. Rasheed et al., “An analytical study to predict the future of Pakistan’s energy sustainability versus rest of South Asia,” Sustain. Energy Technol. Assessments, vol. 39, p. 100707, Jun. 2020, doi: 10.1016/j.seta.2020.100707.

[6] A. Rehman, A. Rauf, M. Ahmad, A. A. Chandio, and Z. Deyuan, “The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: evidence from Pakistan,” Environ. Sci. Pollut. Res., vol. 26, no. 21, pp. 21760–21773, Jul. 2019, doi: 10.1007/s11356-019-05550-y.

[7] N. Y. Amponsah, M. Troldborg, B. Kington, I. Aalders, and R. L. Hough, “Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations,” Renewable and Sustainable Energy Reviews, vol. 39. Elsevier Ltd, pp. 461–475, Nov. 2014, doi: 10.1016/j.rser.2014.07.087.

[8] Muteri et al., “Review on life cycle assessment of solar photovoltaic panels,” Energies, vol. 13, no. 1. MDPI AG, Jan. 2020, doi: 10.3390/en13010252.

[9] M. S. Nazir, N. Ali, M. Bilal, and H. M. N. Iqbal, “Potential environmental impacts of wind energy development: A global perspective,” Current Opinion in Environmental Science and Health, vol. 13. Elsevier B.V., pp. 85–90, Feb. 2020, doi: 10.1016/j.coesh.2020.01.002.

[10] A. N. Rollinson, “Fire, explosion and chemical toxicity hazards of gasification energy from waste,” J. Loss Prev. Process Ind., vol. 54, pp. 273–280, Jul. 2018, doi: 10.1016/j.jlp.2018.04.010.

[11] E. T. Sayed et al., “A critical review on environmental impacts of renewable energy systems and mitigation strategies: Wind, hydro, biomass and geothermal,” Sci. Total Environ., vol. 766, p. 144505, Apr. 2021, doi: 10.1016/j.scitotenv.2020.144505.

[12] N. A. Ludin et al., “Prospects of life cycle assessment of renewable energy from solar photovoltaic technologies: A review,” Renewable and Sustainable Energy Reviews, vol. 96. Elsevier Ltd, pp. 11–28, Nov. 2018, doi: 10.1016/j.rser.2018.07.048.

[13] C. kang Gao et al., “Environmental impact analysis of power generation from biomass and wind farms in different locations,” Renew. Sustain. Energy Rev., vol. 102, pp. 307– 317, Mar. 2019, doi: 10.1016/j.rser.2018.12.018.

[14] P. Dutta, S. Mahatha, and P. De, “Impact Assessment and Project Appraisal A methodology for cumulative impact assessment of opencast mining projects with special reference to air quality assessment,” 2012, doi: 10.3152/147154604781765905.

[15] L. Canter and B. Ross, “State of practice of cumulative effects assessment and management: The good, the bad and the ugly,” Impact Assessment and Project Appraisal, vol. 28, no.

[16] 4. Taylor & Francis Group , pp. 261–268, Dec. 2010, doi: 10.3152/146155110X12838715793200.

[17] N. Stylos and C. Koroneos, “Carbon footprint of polycrystalline photovoltaic systems,” J. Clean. Prod., vol. 64, pp. 639–645, Feb. 2014, doi: 10.1016/j.jclepro.2013.10.014.

[18] I. E. Agency., Benign energy? : the environmental implications of renewables. Paris: Organisation for Economic Co-operation and Development, 1998.

[19] M. A. P. Mahmud, N. Huda, S. H. Farjana, and C. Lang, “Environmental impacts of solar-photovoltaic and solar- thermal systems with life-cycle assessment,” Energies, vol. 11, no. 9, p. 2346, Sep. 2018, doi: 10.3390/en11092346.

[20] V. Fthenakis and H. C. Kim, “Life-cycle uses of water in U.S. electricity generation,” Renew. Sustain. Energy Rev., vol. 14, no. 7, pp. 2039–2048, Sep. 2010, doi: 10.1016/j.rser.2010.03.008.

[21] M. Z. Akber, M. J. Thaheem, and H. Arshad, “Life cycle sustainability assessment of electricity generation in Pakistan: Policy regime for a sustainable energy mix,” Energy Policy vol. 111, pp. 111–126, Dec. 2017, doi: 10.1016/j.enpol.2017.09.022.

[22] J. E. Lovich and J. R. Ennen, “Wildlife conservation and solar energy development in the desert Southwest, United States,” Bioscience, vol. 61, no. 12, pp. 982–992, 2011, doi: 10.1525/bio.2011.61.12.8.

[23] A. Briones-Hidrovo, J. Copa, L. A. C. Tarelho, C. Gonçalves,

[24] T. Pacheco da Costa, and A. C. Dias, “Environmental and energy performance of residual forest biomass for electricity generation: Gasification vs. combustion,” J. Clean. Prod., vol. 289, p.125680, Mar. 2021, doi: 10.1016/j.jclepro.2020.125680.

[25] S. K. Sansaniwal, M. A. Rosen, and S. K. Tyagi, “Global challenges in the sustainable development of biomass gasification: An overview,” Renewable and Sustainable Energy Reviews, vol. 80. Elsevier Ltd, pp. 23–43, Dec. 2017, doi: 10.1016/j.rser.2017.05.215.

[26] K. Stolecka and A. Rusin, “Analysis of hazards related to syngas production and transport,” Renew. Energy, vol. 146, pp. 2535–2555, Feb. 2020, doi: 10.1016/j.renene.2019.08.102.

[27] A. Devanshu, S. Mamta, and S. Brijendra, “Challenges and Environmental Impacts of Biomass Energy in South Asia,” Asian J. Biotechnol. Bioresour. Technol., pp. 1–12, Apr. 2019, doi: 10.9734/ajb2t/2019/v5i130050.

[28] M. Ozoemena, W. M. Cheung, and R. Hasan, “Comparative LCA of technology improvement opportunities for a 1.5-MW wind turbine in the context of an onshore wind farm,” Clean Technol. Environ. Policy, vol. 20, no. 1, pp. 173–190, Jan. 2018, doi: 10.1007/s10098-017-1466-2.

[29] A. Botelho, P. Ferreira, F. Lima, L. M. C. Pinto, and S. Sousa, “Assessment of the environmental impacts associated with hydropower,” Renewable and Sustainable Energy Reviews, vol. 70. Elsevier Ltd, pp. 896–904, Apr. 2017, doi: 10.1016/j.rser.2016.11.271.

[30] P. D. Schomer and P. K. Pamidighantam, “A critical analysis of the ‘Wind Turbine Health Impact Study: Report of Independent Expert Panel,’” J. Acoust. Soc. Am., vol. 134, no. 5, pp. 4096–4096, Nov. 2013, doi: 10.1121/1.4830962.