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Antecedents of Green Energy Transition Adoption: A Meta-Analytic Assessment

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Abstract

The move toward renewable energy sources (RES) is also a growing trend driven by environmental concerns, economic competitiveness, and technological maturity. The paper uses a quantitative meta-analytic method to integrate the emerging literature using three expert lenses (environmentalist, economist, and electrical engineer). Peer-reviewed journal articles were systematically examined using PRISMA-based procedures to examine the environmental impacts, economic performance, and technical efficiency of renewable energy systems. The results indicate that the RES implementation provides meaningful greenhouse gas reductions, with a median CO_2 reduction of about 313.68 t/GWh, and that the effects of land-use and biodiversity are concentrated and can be controlled through proper planning and regulation. Renewable energy has been shown to be economically competitive, as evidenced by median levelized costs close to international standards and an average payback period of approximately 7.84 years. Technically, the photovoltaic systems have matured and operate reliably, with an average performance ratio of 0.77 and good scalability between installed capacity and annual output energy. Overall, the combined evidence demonstrates that renewable energy transitions offer environmental, economic, and sustained technical benefits, and they are appropriate as a core approach to sustainable energy systems.

Keywords
Capacity factor, energy yield, payback time, performance ratio, and renewable energy sources

1. Introduction

For decades, worldwide, people have relied on fossil fuels for energy production (Azni et al., 2023). Historically, the estimated economically recoverable coal resources would last approximately 1,500 years at the current worldwide rate of consumption, assuming existing technology is maintained. In contrast, reserves of natural gas would last only 120 years, or perhaps 2 or 3 times that long, if the much higher costs of recovering less accessible gas from unconventional sources were accepted or if methods were developed to recover it more economically. However, the gas resources might last only 55 years if natural gas were substituted for coal in all applications (Sanghvi et al., 1990). Furthermore, approximately 54% of the world's population has resided in urban areas since 2014, and this figure is projected to increase to 66% by 2050, according to the United Nations Department of Economic and Social Affairs (2014). Covering only 2% of the world's surface, cities account for approximately 75% of global resource consumption (Pacione, 2009). According to Zarco-Perinan et al. (2021), household consumption increases with higher population density in the city.

This study synthesizes evidence on the impacts of transitioning toward RES, both benefits and trade-offs from three expert lenses - environmentalist, economist, and electrical engineering - to provide decision-relevant insights for stakeholders and policymakers on transition pathways from nonrenewable to renewable energy sources. The study employs a quantitative meta-analysis to assess the global need to transition to renewable energy. To achieve a more substantial impact, this research emphasizes the importance of systematic approaches and progressive thinking in advancing renewable energy transitions (Dirma et al., 2024).

1.1 Objectives

Despite significant growth in studies on renewable energy transitions, a gap persists in the literature for empirical research that simultaneously explores the net benefits of these transitions from an integrated multi-lens perspective (Adnan et al., 2024). Most prior studies examine renewable energy transitions from only one lens (environmental, economic, or technical), leading to a fragmented understanding. The study simultaneously evaluates renewable energy transitions through three expert lenses—environmentalist, economist, and electrical engineer—to provide a holistic, evidence-based synthesis.

2. Literature Review

The synthesis of the literature review assesses the need for renewable energy from three different expert lenses: environmentalists, economists, and electrical engineers. These lenses are identified as drivers of the green energy transition, based on the study by Muhire et al. (2024). Political, legal, and social factors are not treated as primary lenses; the focus remains on techno-economic and environmental mechanisms. Each lens is provided with pre-determined factors that could influence renewable energy transitions. New emerging factors will be documented to avoid confirmation bias.

2.1 Environmentalist Lens Pre-Determined Factors

Multiple studies have highlighted the importance of environmental factors, particularly in reducing carbon emissions and addressing various environmental concerns (Han et al., 2025; Idroes et al., 2024; Wang et al., 2025). According to Kamali Saraji & Streimikiene (2023), the environmental pillar encompasses challenges related to climate change, environmental pollution, the consumption of natural resources, and land use. The pre-determined factors are the following:

A. **Carbon Emission.** Refers to the process through which carbon dioxide is released into the atmosphere as a byproduct of the burning of fuels that contain carbon, i.e., fossil fuels, oil, natural gas, coal, etc. (Korkmaz et al., 2023).
B. **Land Use.** Denotes the sum of human activities and arrangements aimed at harnessing terrestrial ecosystem services (Erb, 2015).
C. **Species Richness.** Refers to the number of species within a defined region, which is obtained through sampling or via a census (Moore, Diversity, Taxonomic versus Functional, 2013).

To promote environmental sustainability and reduce carbon emissions, Hassan (2024) recommends that policymakers prioritize encouraging renewable energy sources, such as hydropower, wind, and solar energy, through investment, subsidies, and regulatory frameworks to facilitate a transition away from carbon-intensive energy sources.

2.2 Economist Lens Pre-Determined Factors

Economic indicators are needed to assess the financial effect on the evaluation of RES (Liu, 2014). The development of RES significantly impacts economic growth, and its effects can be assessed across various aspects (Dirma et al., 2024). In general, the predetermined factors for the economist's lens are the levelized cost of electricity, the tariff, and the payback period.

A. **Levelized cost of electricity.** The costs of electricity production, system development, and the electricity tariff are estimated using the levelized cost of electricity (LCOE) (Wyszomierski et al., 2025).
B. **Feed-in tariff.** One of the most accepted mechanisms of pricing policy. According to the Building Energy Research Center at Tsinghua University (2024), increasing the tariff will significantly improve the power system's economic efficiency.
C. **Payback time.** Refers to a measure of how quickly the system generates cash flows to cover the initial investment (Liu, 2014).

2.3 Electrical Engineer Lens Pre-Determined Factors

In this study, the electrical engineer lens represents the technological innovation of RES. Technological innovation in renewable energy is a key driver of the energy transition (Wang et al., 2021; Johnston et al., 2010). According to Han et al. (2025), a positive association exists between technological innovation and the broader adoption of renewable energy sources, underscoring how technological advancements facilitate the shift toward sustainable energy solutions. For an electrical engineer lens, the pre-determined factors are the following:

A. **Energy yield.** The measure of usable energy output from a system compared to the energy input required to operate that system (Sustainability Directory, 2025).
B. **Performance ratio.** Indicates performance, energy, and system energy losses and investigates the operational efficiency (Jamil et al., 2022).
C. **Capacity factor.** The ratio of its actual output over a period of time to its nominal potential production if operating constantly at full nameplate capacity over the same period of time (Muratori et al., 2017).

These metrics are technology-sensitive and can be predicted in advance before commissioning, making them an appropriate set of predetermined indicators of innovation effects.

3. Methods

This study employs quantitative meta-analysis to assess the global need for renewable energy. This study recognizes certain limitations in its scope and analytical framework. The assessment primarily focuses on pre-determined factors. While these factors are appropriate for evaluating techno-economic feasibility, they may not fully capture all operational and organizational dynamics. Although engineering-relevant measures, such as process efficiency, OPEX reduction (Novarika et al., 2024), and system reliability indices, are included to enhance the analysis, the study's findings remain constrained by data availability and contextual specificity. As such, the results may vary under different environmental conditions, organizational structures, or technological configurations. Further, the number of samples is below thirty, so the results may not apply globally, but rather to the local population only, and findings must be interpreted cautiously.

4. Data Collection

A review of existing literature using quantitative meta-analysis will be utilized. To ensure proper reporting, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed (Moher et al., 2009). Three expert lenses were considered: Environmentalist, Economist, and Electrical Engineer. The findings provided empirical evidence of the need to transition towards renewable energy. The research method used in this study is shown in Figure 1 (B.A. Jnr, 2020). This illustrates the research method's subprocesses, including the search strategy and data sources, inclusion and exclusion criteria, quality assessment, data extraction, and findings (Figure 1).

Figure 1. Research methodology process

4.1 Search Strategy

A systematic literature review was conducted using the most well-known electronic databases, including IEEE Xplore, Taylor & Francis, and SpringerLink. Customized advanced searches were employed for each expert lens, utilizing the Boolean operators (AND/OR/NOT) and the most relevant keywords. Only journal articles are included and must be published from 2021 to 2025.

4.1.1 Environmentalist Lens

The related keywords used in the environmentalist lens advanced search were renewable energy, carbon footprint, carbon, emission, reduction, CO_2e, species richness, species diversity, habitat loss, land use, land footprint, ecosystem impact, wildlife, mortality, flora, river ecology, environmental flow, underwater noise, benthic, and freshwater ecology. These keywords were predetermined based on established concepts in renewable energy and the environment. The list was developed before the search. The initial articles found were 377. Second, all article titles were checked for relevance to the study, and 317 articles were excluded. Furthermore, 29 journal articles were excluded as not relevant to the study after scrutinizing their abstracts. After screening the paper's content and conducting a quality assessment, 18 additional articles were excluded. The remaining 13 papers were found to meet the criteria and then used for the meta-analysis as 13 datasets.

4.1.2 Economist Lens

The related keywords used in the Economist Lens advanced search were renewable energy, economy, levelized cost, LCOE, carbon tax, carbon price, incentive, feed-in tariff, payback period, and investment recovery. These keywords were pre-determined factors based on established concepts in renewable energy and economics. The list was developed before the search. The initial articles found were 63. Second, all article titles were checked for relevance to the study, and 31 articles were excluded. Furthermore, five journal articles were excluded as not relevant to the study after reviewing their abstracts. After screening the paper's content and conducting a quality assessment, eight additional articles were excluded. The remaining 19 papers were found to meet the criteria and then used for the meta-analysis as 19 datasets.

4.1.3 Electrical Engineer Lens

The related keywords used in the electrical engineer lens advanced search were renewable energy, capacity factor, specific yield, and performance ratio. These keywords were pre-determined factors based on established concepts in renewable energy and electrical engineering. The list was developed before the search. The initial articles found were 48. Second, all article titles were checked for relevance to the study, and nine articles were excluded. Further, eight journal articles were also excluded as not relevant to the study after reviewing their abstracts. After screening the paper's content and quality assessment, seven additional articles were excluded. The remaining 24 papers were found to meet the criteria and then used for the meta-analysis as 24 datasets.

4.2 Inclusion and Exclusion Criteria

Inclusion criteria are the elements of an article that must be present for it to be eligible for inclusion. In contrast, exclusion criteria are the elements of an article that disqualify the study from inclusion in a literature review (University of Missouri–St Louis Libraries, n.d.). The inclusion and exclusion criteria must be established before the review begins (UTHealth Houston School of Public Health Library & Graduate Communication Center, n.d.). In this study, journal articles are eligible for inclusion if they discuss renewable energy and its impact on the environment, economy, and electrical engineering, or its related factors, as viewed through the lens of an expert. Papers that are not written in English were excluded.

4.3 Quality Assessment Criteria

The quality assessment of individual studies included in meta-research manuscripts is a fundamental step in supporting the evidence synthesized by meta-research (Dreier, 2013; Burns et al., 2011). The study's relevance must focus on renewable energy and its impact on the environment, economy, and electrical engineering. Similarly, journal articles were cross-checked to determine whether they are indexed in the Scopus and/or ISI Web of Science databases. This is intended to establish the credibility of the selected journal articles before conducting the meta-analysis.

4.4 Data Extraction

This aims to extract relevant findings from the existing literature, based on research questions, following a quality assessment. Therefore, the data on land-use intensity, biodiversity, and CO2 reduction were extracted from each journal article through an environmentalist's lens. For the economic lens, the levelized cost of electricity (LCOE), payback period, tariff, and annual life-cycle costs were also extracted. For the electrical engineer lens, the energy yield, performance ratio, and capacity factor were then extracted.

5. Results and Discussion

This section presents findings from the review based on existing studies that discuss the advantages of shifting towards renewable energy in terms of its environmental, economic, and electrical engineering impacts. Results are presented as indicative patterns due to the small sample sizes (N) across studies.

5.1. Environmentalist Lens

The descriptive statistics results are shown in Table 1. The CO_2 reduction data has three observations that can be used (eleven entries are not available). The reported values range between 0 and 602541.90 t/GWh, with a mean of 200951.86 t/GWh, a median of 313.68 t/GWh, and a standard deviation of 283967.07 t/GWh. The size of the distribution is large and contains an entry of zero. The values range from -69.57% to +169.23%, with a mean of +22.65% and a median of -31.71%. The standard deviation has been reported as 1.05.

Table 1. Descriptive statistics results for CO_2 reduction, biodiversity, footprint, and mortality

Statistics	**Carbon Emission Reduction (t/GWh)**	**Biodiversity, Footprint & Mortality**
Count	3	3
Min	0	-69.57%
Max	602541.90	169.23%
Mean	200951.86	22.65%
Median	313.68	-31.71%
Std Dev	283967.07	1.05
Missing	11	11

Table 2 compares the land-use intensity of eight RETs, expressed in kilowatt squared per terawatt-hour (kW2/TWh) and as a min-max normalized score. The range of intensities reported is between 0.11 and 20.2 kW^2/TWh, which is approximately 184 times. Nuclear power (0.11; 0.00 normalized) is the weakest, followed by hydroelectric power (0.29; 0.01). At the lower end of the spectrum are coal (1.52; 0.07), pumped storage (1.73; 0.08), and wind (1.75; 0.08). The values of photovoltaic solar and concentrating solar power are high (11.7, 0.58, and 12.86, 0.63). The peak intensity is observed in open-cycle gas turbine/diesel systems (20.2; 1.00), which sets the upper limit of the normalization process. Overall, technologies rank from lowest to highest land-use intensity as: nuclear < hydro < coal ≈ pumped storage ≈ wind < solar < CSP < OCGT/diesel.

Table 2. Land use intensity

Technology	**kW^2/TWh**	**Normalized Values**
Nuclear	0.11	0
Hydro	0.29	0.01
Coal	1.52	0.07
Pumped Storage	1.73	0.08
Wind	1.75	0.08
Solar	11.7	0.58
CSP	12.86	0.63
OCGT (Diesel)	20.2	1.00

The area of developed land, as shown in Table 3, was strongly positive, with an increase from 59.34 to 199.34, representing a growth of 140.00 (235.93%). This growth is largely offset by a loss of forest cover, which decreased by 122.48ha, from 6,499.77ha to 6,377.29ha (a percent change of 1.88%). The decreases recorded in cropland (–15.32 ha; –1.64%), bush wood (–1.06 ha; –1.33%), grassland (–0.86 ha; –5.09%), and wetland (–0.29 ha; –1.71%) were subordinate. In any case, the expansion of built-up regions is highly correlated with a reduction in natural and agricultural land cover, with the largest loss occurring in the forested section (Table 3).

Table 3. Descriptive statistics for land use change

Land Type	**Before (ha)**	**After (ha)**	**Change (Δ ha)**	**% Change**
Forest	6499.77	6377.29	-122.48	-1.88%
Bushwood	79.93	78.87	-1.06	-1.33%
Grassland	16.88	16.02	-0.86	-5.09%
Wetland	16.96	16.67	-0.29	-1.71%
Cropland	931.86	916.54	-15.32	-1.64%
Built-up	59.34	199.34	140	235.93%

Table 4 presents the descriptive results for biodiversity after RET installation. The macroinvertebrate taxa decline from 23 to 7, a reduction of 16 taxa (-69.57%). Bird abundance increases from 13 to 35, a 22-individual increase (+169.23%). Bird species richness decreases from 41 to 28, a loss of 13 species (-31.71%).

Table 4. Descriptive statistics for biodiversity

Metric	**Before**	**After**	**Delta (Δ)**	**% Change**
Macroinvertebrate taxa	23	7	-16	-69.57%
Bird abundance	13	35	22	169.23%
Bird species richness	41	28	-13	-31.71%

The environmental literature is unequivocal about system-level GHG benefits, while emphasizing that local land- and water-based effects are context-dependent and manageable when acknowledged early. The compiled indicators mirror both sides. CO_2 reduction reports show a median of approximately 313.68 t/GWh. Land-use intensity benchmarks place technologies along a clear gradient, while the before-and-after table in our example site shows modest decreases in natural classes alongside an increase in built-up area. Biodiversity changes are mixed in the small set.

5.2 Economist Lens

The results of descriptive statistics for the economist lens are shown in Table 5. Regarding the levelized cost of electricity (LCOE), there are 14 observations, with 6 data points missing. The values range from 0.03 to 0.46, with a mean of 0.17, a median of 0.12 (IQR = $0.18, N = 14), and a standard deviation of 0.14. Regarding the payback period, 9 observations and 11 data points are missing. Payback years range between 4.3 and 10 years, with a mean of 7.84, a median of 8.3, with a standard deviation of 1.83 years. Regarding the tariff, there are 5 observations, and 15 are missing. The reported rates range from 0.01 to 0.12, with a mean of 0.07, a median of 0.08, and a standard deviation of 0.05. A new emerging factor was also recorded: annual life-cycle savings. The number of observations reported for annual savings of the life cycle is 4, and the remaining data set (16 observations) is missing. The savings will range from $2,340/year to $24,796,370/year, with a mean of $12,400,817.75/year and a median of $12,402,280.50/year, and a standard deviation of 12,395,552.42.

Table 5. Descriptive statistics result for the economist lens

Statistics	**Levelized Cost of Electricity**	**Payback Period**	**Tariff**	**Annual Life Cycle Savings**
Count	14	9	5	4
Min	0.03	4.30	0.01	2,340
Max	0.46	10	0.12	24,796,370
Mean	0.17	7.84	0.07	12,400,817.75
Median	0.12	8.30	0.08	12,402,280.50
Std Dev	0.14	1.83	0.05	12,395,552.42
IQR	0.18	-	0.11	-
Missing	6	11	15	16

Economic studies repeatedly report competitive LCOE and recoverable paybacks, with differences explained by familiar levers (CAPEX levels, O&M predictability, tariffs/interconnection rules). The pooled figures match that picture: LCOE median is at the international baseline. The tariff entries are few, and the margin (tariff - LCOE) pairs are limited, showing both above-parity and below-parity cases - exactly what mixed geographies and project maturities would yield. Annual life-cycle savings are scale-driven, illustrating that benefits can be substantial when generation is large.

5.3 Electrical Engineering Lens

The results of descriptive statistics for the electrical engineering lens are shown in Table 6. Available installed capacities range between 3.30kW and 750,000kW. The calculated mean is 65,892.36 kW, the standard deviation is approximately 166,190.32 kW, and the median capacity is 1,000 kW. The large distance between the mean and the median indicates strong right skewness in the portfolio, characterized by a high number of small- to medium-scale systems and a few utility-scale assets, which, proportionately, increase the mean. Therefore, when making assertions about typical plants or conducting benchmarking activities, one should use median values or size-banded characterization, such as 1MW, 1-50MW, and >50MW, to reduce bias introduced by large-scale installations.

Its annual power output ranges from 1.372 MWh to 1,167,447 MW. The average is 85,645.03 MWh (standard deviation is approximately 264,177.70 MWh); the median is 652.62 MWh. The distribution of capacity follows a capacity skew, with some plants producing significantly more energy per annum than most smaller plants. Before using these figures to compare plant performance, ensure the outputs reflect a complete calendar year for each plant; incomplete years of metering would not only inflate variability but also skew some values.

Table 6. Descriptive statistics result for the electrical engineering lens

Statistics	**Installed Capacity (kW)**	**Annual Energy Output (MWh)**	**Performance Ratio**	**Capacity Factor (%)**
Count	22	19	14	17
Min	3.30	1.372	0.60	0.97
Max	750000	1167447	0.95	55.40
Mean	65892.36	85645.03	0.77	0.24
Median	1000	652.62	0.77	19.32
Std Dev	166190.32	264177.70	0.08	0.14
P(25)	64	-	0.72	-
P(75)	11750	-	0.81	-
IQR	11686	-	0.09	-
Missing	2	5	10	7

The PR values range from 0.60 to 0.95, with a mean of 0.77 (standard deviation 0.08) and a median value of 0.77. The distribution has a focal point, which is characteristic of well-designed photovoltaic systems, meaning that conversion efficiency and system losses are typically under control in plants where PR data is available. However, 10 assets lack

PR information, which may bias the findings in favor of well-monitored sites. The conclusions must then be assumed to be more of an indication than a representative of the whole fleet.

The capacity factor (CF) ranges from 0.97% to 55.40%. The average CF is 0.24 (standard deviation is about 0.14), and the median is 19.32. The central value of the median is more plausible; hence, it is used, and CFs above 35-40% must be flagged. Each calculation of the CF must be set on a uniform, full-year basis.

The descriptive analysis revealed a broad capacity range and corresponding annual outputs, confirming the scalability of renewable generation. The mean performance ratio and capacity factor are consistent with international performance standards (IEA PVPS, 2023), demonstrating stable conversion efficiency under diverse climatic and operational conditions. Variations in performance across systems reflect the influence of design, technology, and maintenance practices, supporting the need for continued optimization and investment in renewable infrastructure.

5.3.1 Correlation of Electrical Pre-determined Factors

Performance Ratio and Capacity Factor. This moderate positive relationship indicates that as the performance ratio increases, the capacity factor also tends to rise. Practically, this means systems operating more efficiently also exhibit better utilization of installed capacity. The relationship strength is moderate, likely because other environmental or design factors (such as irradiance variability, inverter type, or system age) also influence utilization. The result is shown in Figure 2.

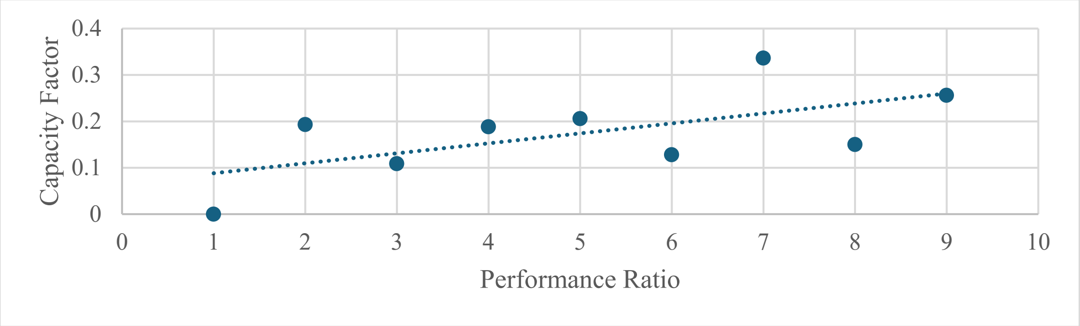

Figure 2. Performance ratio and capacity factor correlation

Capacity and Annual Output. This result indicates a near-proportional relationship between installed capacity and total energy generation (Very Strong), even after converting both variables to a consistent unit (MW) as shown in Figure 3. This validates the scalability of renewable energy systems; larger plants predictably generate more output. The strength (r > 0.9) confirms that capacity is the dominant driver of generation performance.

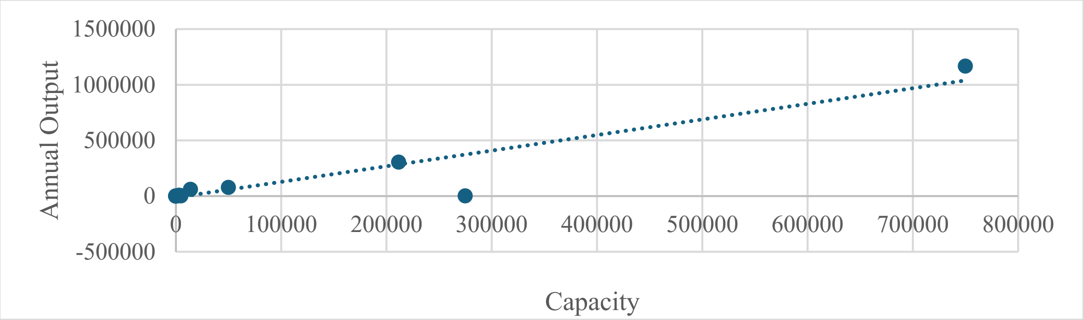

Figure 3. Capacity and annual output correlation

Capacity and Performance Ratio. This weak, slightly negative relationship suggests that, as system size increases, the performance ratio does not improve significantly and may even decline slightly, as shown in Figure 4. This suggests that as renewable energy technology installations scale up, minor efficiency losses arise from increased system complexity, maintenance requirements, and cumulative conversion losses. Such findings are consistent with patterns observed in large-scale PV performance benchmarking studies, in which smaller distributed systems often exhibit higher relative performance.

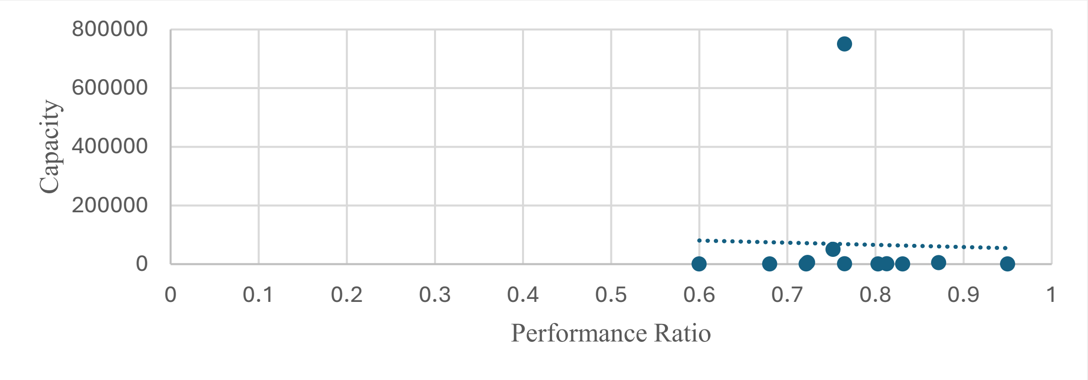

Figure 4. Capacity vs performance ratio

Furthermore, the regression analysis in Table 7 reveals three distinct patterns. The first is that the correlations between PR and CF are low (Multiple R = 0.46), and the model accounts for only about 21 percent of the variance ($R^2 = 0.21$). Adjusted R^2 after the correction of sample size is approximately 0.08. This relationship should be viewed with caution, as it is based on a small sample size (n = 8), making estimates highly sensitive to individual data points. On the contrary, Capacity has a very strong linear dependence on Annual Output. The correlation is good (Multiple R = 0.94) and the model accounts for a significant percentage of the variation in the outcomes ($R^2 = 0.88$; adjusted $R^2 = 0.87$) of 18 observations. This implies that in the sample, an adjustment in Capacity is closely proportional to an adjustment in Annual Output. The standard error in this case is relatively large and may indicate that the dependent variable is large, not due to a poor fit; however, units and consistency checks would be advisable. Lastly, the relationship between PR and Capacity does not seem significant. The correlation is close to zero (Multiple R = 0.03), and the model explains an almost negligible amount of variation ($R^2 = 0.001$). The negative adjusted R-squared value (-0.10) indicates that the regression does not offer any improvement over a simple mean model for the 12 observations used.

Table 7. Regression statistics

Variable Pairs	**Multiple R**	**R Square**	**Adjusted R Square**	**Standard Error**	**Observations**
Performance Ratio and Capacity Factor	0.46	0.21	0.08	0.07	8
Capacity and Annual Energy Output	0.94	0.88	0.87	100135992	18
Capacity and Performance Ratio	0.03	0.00098	-0.10	0.10	12

Across the technical literature, renewables, especially modern PV, are described as mature, dependable technologies whose output varies for explainable reasons (climate, irradiance, site conditions, routine operations). The dataset reflects that pattern. Performance is clustered, not erratic. Scale behaves predictably: Capacity-Annual Output r ≈ is very strong, confirming that larger systems produce proportionally more energy. Drivers of efficiency are not dominated by size in this set (Capacity-PR r ≈ weak/none). Although PR / CF r ≈ moderate, the regression on that subset is not statistically significant (p ≈ 0.256), which cautions against causal claims.

6. Conclusion

The paper demonstrates that an environmental, economic, and electrical-engineering synthesis of the literature indicates that such a shift yields measurable benefits and mature operational effects. Environmentally, renewable initiatives eliminate carbon emissions by a median of about 313.68 t/GWh, have localized impacts on biodiversity (median -31.71 and present land-use trade-offs manageable by careful location and observation). Economically, renewables have been competitive, with a median levelized cost of electricity (LCOE) of $0.12/kWh and the average payback period of 7.84 years. The mean tariff is $0.07/kWh. The median annual savings of $12,402,280.50 was also reported. Technically, the PV systems appear to be fully functional, as the average performance ratio of approximately 0.77 met international standards. The installed capacity was almost identical to the annual output (r = 0.94), and the performance ratio was moderately related to the capacity factor (r = 0.46). The study also showed that the performance ratio was not influenced by the system's capacity. Finally, the results supported the idea that the renewable energy transition is not only environmentally required but also economically viable and technologically advanced, which aligns with the view that it is a beneficial component of sustainable energy systems and long-term energy policy.

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