

THE ECONOMIC IMPACT OF SOLAR ENERGY ADOPTION ON INDUSTRIAL GROWTH IN PAKISTAN

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DOI:<https://doi.org/10.5281/zenodo.17424149>

Keywords

Solar Energy Adoption, Renewable Energy, Industrial Growth, Economic Impact, Pakistan

Article History

Received: 02 September 2025

Accepted: 11 October 2025

Published: 23 October 2025

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Abstract

Solar energy utilization has developed as a viable option, providing clean, affordable, and consistent power to the industrial sector of Pakistan. This research examines the effect of solar energy adoption on industrial performance, operational efficiency, and cost reduction in Pakistan. As it follows a quantitative research approach, the research uses secondary data obtained from government reports and industry sources and employs correlation and multiple regression analysis to determine the extent of association between solar energy adoption, government subsidies, operational reliability, and industrial growth. Evidence suggests that longer operational hours through secure electricity greatly increase industrial production, with solar uptake and subsidies having positive though less statistically significant impacts. The results highlight the need for holistic policies integrating solar promotion, subsidized targeting, and stable energy infrastructure to increase industrial development. This study offers useful knowledge for policymakers, investors, and industrial stakeholders alike, underscoring the economic merit of solar energy and paving the way for Pakistan's transition to sustainable, low-carbon, and energy-secure industrial development.

Chapter#1. Introduction:

Driving industrial expansion and sustaining economic growth depend much on energy (Jie et al., 2023). Contributing considerably to GDP, employment, and export revenues, the industrial sector is regarded in Pakistan as one of the main pillars of the national

economy (Ajmair 2014). The industry has, though, long battled with ongoing energy shortages growing gasoline expenses, and erratic power supply. These issues have significantly hampered productivity efficiency and competitiveness. Many sectors experience regular power outages that disturb

operations, raise manufacturing costs, and restrict their capacity for growth. Pakistan's industrial output has therefore frequently been under its possibility; energy instability is still one of the main obstacles to sustainable development. growth in the economy (Ali et al. 2024).

Responding to these obstacles, interest has progressively swung towards renewable energy sources, especially solar power. Pakistan is ideally situated geographically to utilize solar energy, with plenty of sunlight year round (Mirza et al. 2003). Solar power is clean, sustainable and provides a long term answer to the increasing energy needs. Over the last ten years, the uptake of solar energy in several industries including homes, agriculture, and business has progressively grown. Many industrial facilities are now putting solar systems to lessen reliance on the national grid, lower operational expenses, and ensure a reliable supply of energy (Mekhilef et a., 2013).

Recognizing the capacity of renewable energy to increase manufacturing output and promote sustainable development, the government has also enacted legislation and incentives to foster investment. Besides lowering energy costs, the use of solar energy improves the general efficiency and competitiveness of businesses (Owen et al., 2006).

Greater production stability and environmental preservation are made possible for businesses by moving toward renewable energy, therefore helping to

reduce carbon emissions. Furthermore, solar energy can help to lighten the load on Pakistan's already overextended power grid. For companies looking to boost their performance and help the national economy, solar energy is a desirable choice since it provides all of these advantages. Though solar energy is grabbing more and more attention, there is still little study on its straight economic effects on Pakistani industrial expansion. Most current research has looked at renewable energy in broad strokes, but not particularly at how solar energy affects industrial output, expenses, and profitability. This difference emphasizes the need of more investigation to know how using solar energy supports industrial expansion and financial development. This research wants to look into how using solar energy can affect the economy and help industries grow in Pakistan. It will explore how solar energy can improve how well things are made, lower costs, and make companies more competitive. The results of this study will offer useful information for those who make laws, investors, and people in charge of businesses. By showing the economic benefits of using solar energy, this research can influence future energy rules that support the use of clean energy and promote friendly growth for industries in Pakistan.

Renewable power capacity by region

| Region | Capacity (GW) | Global Share (%) | Change (GW) | Growth (%) |
|-----------------------------------|---------------|------------------|-------------|------------|
| North America | 573 | 12.9% | +45.9 GW | +8.7% |
| Central America and the Caribbean | 19 GW | 0.4% | +0.6 GW | +3.2% |
| South America | 313 GW | 7.0% | +22.5 GW | +7.8% |
| Europe | 849 GW | 19.1% | +70.1 GW | +9.0% |
| Middle East | 40 GW | 0.9% | +3.3 GW | +9.0% |
| Africa | 67 GW | 1.5% | +4.2 GW | +6.7% |
| Eurasia | 131 GW | 2.9% | +8.3 GW | +6.8% |
| Asia | 2382 GW | 53.6% | +421.5 GW | +21.5% |
| Oceania | 74 GW | 1.7% | +8.7 GW | +13.3% |

Table 1.1

For the whole data set, see IRENA'S (2025) Renewable capacity statistics 2025 available at www.irena.org/Data/Statisticalpublications/Yearbook. Although 2024 saw the greatest worldwide capacity growth in renewable energy, significant discrepancies continue among nations and areas. Leading this expansion, Asia contributed 421.5GW, or 72.0% of new capacity for a total renewable capacity of 2,382 GW which is 53.6% of all global capacity. Accounting for 373.6 GW of the rise, China was the main participant. With Germany accounting for over 18.8 GW of this growth, Europe added 70.1 GW (9.0%). Still, Ukraine had a large fall in 2024, losing more than 7.5 GW.

Driven mostly by American installations, renewable capability in North America grew by 45.9 GW (8.7%). With a 4.2 GW increase (6.7%), mostly driven by Egypt, Ethiopia, and South Africa, Africa experienced consistent expansion. Capacity in Oceania grew by 8.7 GW (13.3%). mostly from Australian advances. South America continued its rise and increased capacity by 22.4 GW (7.8%). With Saudi Arabia providing over half of this expansion, the middle East added, 3.3GW of new capacity or 9.0%. This worldwide analysis stresses the unequal but strong growth of renewable energy throughout therefore highlighting regional leaders and laggards in the move to cleaner energy sources.

1.2. Problem Statement:

Driving economic expansion, employment creation and export performance depends significantly on Pakistan's industrial sector. Nevertheless, the industry still struggles with serious difficulties resulting from the ongoing energy shortage. Frequent power outages, inconsistent electricity supply, and growing fuel prices have greatly driven production costs up and weakened industrial competitiveness. These energies related problems have hampered production methods, discouraged investment, and restricted the general development potential of Pakistan's industrial base. Though the nation has great solar energy reserves, the acceptance of solar power in the manufacturing industry is still rather modest. Many sectors still rely on costly and environmental damaging conventional and non-renewable energy sources. Solar panel power offers a chance to lower power prices raise production efficiency and support environmental sustainability. The financial consequences of using solar energy in the industrial sector of Pakistan, however, have not been completely studied.

Most current research in Pakistan have mostly concentrated on the growth of renewable energy, with not much focus on the particular economic effects of solar energy on industrial performance and productivity. Consequently, not much is known about how the use of solar energy helps to spur industrial expansion and general economic growth. This lack of supporting data makes it challenging for investors, policymakers, and industrial decision-makers to create successful plans and policies promoting solar energy use and guaranteeing sustainable industrial growth. The main issue under investigation here is thus the restricted knowledge of how adoption of solar energy affects Pakistan's industrial expansion. Developing wise energy policies, encouraging renewable energy investments, and sustaining Pakistan's industrial sector's long-term viability all depend on tackling this vacuum.

1.3. Significance of the Study:

This research is quite important for Pakistan's continuing attempts to reach sustainable industrial and economic development. Long under high energy prices, unstable electric supply, and reliance on imported fossil fuels, the industrial sector of the nation has suffered. This study offers insightful comments on how renewable energy may help industrial growth and lower output by investigating the economic consequences of solar power adoption. expenses, then boost competitiveness in both domestic and world markets. The study is especially important for legislators as it provides factual data to assist in the creation of successful energy and industrial policies. knowing the economic advantages of solar power will enable the government to create focused incentives, grants, and regulation that promote greater use of solar solutions in all sectors. This first Pakistan's long range objectives of attaining energy independence, fostering green growth and fulfilling world commitments for sustainable development. The results of this study can guide investors and industrial stakeholders to make wise judgements regarding the development of renewable energy technologies. The study can motivate businesses to switch to cleaner and more affordable energy sources by showing how solar energy can improve production efficiency and lower operating costs. From an academic viewpoint, this work adds to the already known knowledge base by addressing a gap in empirical research on the connection between solar Energy uptake and industrial expansion in emerging nations, especially Pakistan's. The findings might guide upcoming research on how renewable energy affects economic change. Generally, the research is important since it not only reveals the economic possibilities of solar energy for Pakistan's industrial sector but also backs the worldwide moving towards a more environmentally friendly, low carbon, and energy secure future.

1.4 Research Questions

1. How does solar energy adoption affect industrial growth in Pakistan?
2. Does the use of solar energy help reduce production costs for industries?
3. What role does solar energy play in improving the efficiency and sustainability of Pakistan's industrial sector?

Chapter#2. Literature Review

The world's shift toward renewable energy has emphasized the essential part solar power plays as a sustainable and ecologically friendly source of electricity. Adoption rates for solar photovoltaic (PV) systems remain rather low in many situations even in spite of significant financial incentives and helpful policies. Bauner et al. (2015) looked at household uptake of solar PV in Massachusetts, pointing out that even with substantial state and federal incentives, homes postpone expenditure due to returns uncertainty. Using the option value approach, the research discovered that for Adoption to happen implies that uncertainty considerably extends median adoption time by eight years relative to conventional net present value decision criteria. While policies like rebates and financial incentives were discovered to cut adoption time, their influence is decreased if homes reflect uncertainty, which implies that Encouragement of solar energy adoption depends on lowering investment risk.

From a world point of view, it is evident still more that renewable energy adoption has several advantages. Emphasizing the part renewable energy plays in sustainable development, Adanma et al. 2024 systematically reviewed the economic and environmental effects of renewable energy. With governmental policies and technical innovation being major drivers of adoption, the study emphasized how solar and other renewables help job creation stabilize energy prices and reduce greenhouse gas emissions. The study emphasizes that adoption of renewable energy provides major environmental and financial advantages and that well-considered policy measures are required to raise worldwide usage. Moreover, important influences on solar power acceptance are social and behavioral ones. Studying public perceptions of solar energy in South Korea, Kim et al. (2014) discovered positive effects of system quality,

expected advantages, and confidence on public attitude. While perceived expense acted as a barrier, adopting solar technologies required public attitudes and satisfaction considerably molded adoption plans, according structural equation modeling. Likewise, Arias et al. (2025) looked at public acceptance of solar power projects in Mexico, stressing the importance of age, education, and government-provided financial incentives. *Fostering Adoption*. Higher support for solar projects shown by younger and better-educated people means that targeted awareness campaigns and marketing activities are essential for raising acceptance of society. In Indonesia, Santoso et al. (2024) confirmed these results by demonstrating that although technical considerations have a major impact on uptake, financial advantages including cost reductions Return on investment influences adoption choices far more significantly than anything else. Beyond home energy use, solar adoption has major economic effects. In China, the European Union, and the United States, Zonghan Li (2024) studied how solar energy adoption and regional economic performance interacted. Though gaps in knowledge of impacts on salaries and consumer patterns persist, the study discovered favorable connections between solar adoption, economic expansion, and employment rates. Investigating spatial peer-effects in Connecticut, Graziano et al. (2019) showed that adoption behavior transcends municipal boundaries, therefore suggesting that centered and non-voluntary support measures might provide bigger effects than targeted projects. This study stresses how crucial regional and spatial dynamics are in helping one to grasp solar technology distribution.

Policy design and technical innovation also affect adoption patterns. Adão et al. (2024) created an integrated assessment model including technological spillovers and capital replacement costs, pointing out that renewable energy may need more than just direct subsidies to be advanced. Rather, complementary policies maximizing social welfare and fostering sustainable energy transitions include carbon taxes and internalizing of technology spillovers. Likewise, Timilsina et al. (2012) discovered that even if technical advancements had reduced solar energy prices, obstacles such institutional, financial, legal, and technical were Difficulties persist, hence

sustained policy assistance is needed in developed as well as developing nations to sustain growth.

High potential renewable resource in Pakistan still underutilized is solar power.

Emphasizing the need to diversify energy sources in light of environmental issues and the limited supply of fossil fuels. Pakistan's high solar insolation potential was described by Mirza et al. (2003) who also proposed uses from cookers and solar water heaters to power generation, so reduce dependency on imported fossil fuels and so relieve pressure on forest resources. Pointing out that mismanagement bad planning and past negligence have all contributed to server energy shortages Shakeel et al.,(2016) found structural problems in the electricity industry. The research stresses how crucial renewable energy is to offer long lasting solutions for Pakistan's power issues. Adoption of solar energy in Pakistan depends mostly on policy and institutional frameworks. Raza et al. (2020) investigated renewable energy growth in Rural regions demonstrate that, while urban households use more electricity, rural populations suffer major energy shortages. The research indicated that installing renewable energy projects could help. Improve living standards, job, and financial results. Policy, institutional, financial, market, technical, and social obstacles were found by Mirza et al. (2019) to be main limitations to renewables. energy deployment highlights the need of focused interventions to remove these barriers. Highlighting technical advances such as solar reflectors, Hashmi et al. (2018) said that such improvements were mostly uncharted in Pakistan as a way to raise solar panel efficiency.

Cost and accessibility become major factors influencing solar adoption. According to Qureshi et al. (2017) and Irfan et al. (2019), the high cost of Major obstacles at household level were solar PV systems and a lack of proper government assistance; availability of local merchants and technical support affected adoption decisions. Though there are environmental advantages, the research stressed that financial considerations are crucial for families. In their 2020 study, Irfan and colleagues built on previous work by using the theory of planned behavior to study household intentions to adopt renewable energy. Self-perception of effectiveness, renewable energy awareness, and participatory behavior of neighbors positively influenced adoption, while cost

negatively influenced it. The neutral impact of concern for the environment and the perceived benefits shows that financial and social constraints will need to be resolved alongside public awareness initiatives to promote adoption.

In Pakistan, the organizational adoption of renewable energy is similarly motivated primarily by economic factors. Qamar and colleagues (2022) focused on the adoption of solar energy technology (SET) by Punjabi micro, small, and medium-sized enterprises (MSMEs) and found that enterprise size, perceived ease of use, and SET reliability as important facilitators while the cost of energy, SET price, and competitive pressure were major hindrances. The research concluded that there is a need to focus on cost reduction and financial incentive improvements to promote enterprise adoption. The historical context and existing infrastructure will also influence the adoption landscape. Shakeel et al. 2016 emphasized that decades of energy mismanagement have led to a persistent gap between energy demand and supply, necessitating comprehensive roadmaps for integrating renewable energy sources. Awan et al. 2014 highlights the role of renewable energy in mitigation environmental pollution improving energy reliability and enhancing socio-economic development. Mekhilef et al. 2011 discussed the growing relevance of solar energy in industrial applications including electricity generation, water desalination and chemical processes emphasizing the importance of solar energy for enhancing energy stability and sustainability.

Socio economic evaluation of solar technology utilization also provides insights into potential adoption trends. Jabeel et al. 2024 reported a 65% potential for solar technology adoption in Abbottabad, Pakistan based on income, cost and user friendliness consideration. The study highlighted that solar technologies can address key energy needs and improve quality of life. Similarly, Bhutto et al. 2012 identified barriers and regional potential across Pakistan while Timilsina et al. 2012 and Zafar et al. 2018 emphasized the need for coherent policy frameworks, strong financial commitments and strategic planning to achieve renewable energy targets. In conclusion the literature reveals that solar energy adoption is influenced by a complex interplay of financial technological, institutional and social

factors. Globally adoption enhance economic growth, employment and environmental sustainability. In Pakistan despite substantial solar potential adoption remains limited due to high costs inadequate policy support, institutional inefficiencies and socio-economic barriers. Targeted strategies including financial incentives public awareness campaigns, technological innovations and coherent policy frameworks are essential to maximize solar energy utilization. The evidence indicates that both global experiences and country specific studies underscore the importance of integrated approaches to promote solar energy adoption and achieve sustainable economic, social and environmental outcomes.

Chapter# 3. Research Methodology

3.1 Research Design

This study adopts a **quantitative research design** to examine the economic impact of solar energy adoption on industrial growth in Pakistan. The research focuses on understanding the relationship between solar energy adoption and industrial performance indicators such as Solar Energy adaption, government subsidy on solar, operation hours increase due to reliable electricity. A **cross sectional survey** approach is utilized to, complemented by secondary data from government reports, industry associations, and published statistics. The research design allows for **statistical testing of hypotheses** and identification of key determinants influencing solar energy adoption and its economic implications.

3.2 Data Collection

The study utilizes a Secondary data collection approach:

Secondary data obtained from reports of the Pakistan Bureau of Statistics, Alternative Energy Development Board (AEDB), State Bank of Pakistan, and other relevant industry reports. This data provides contextual insights into solar energy policies, industrial growth trends, and economic indicators.

3.4 Research Variables

The study includes **independent, dependent, and control variables:**

Independent Variable: Solar Energy adaption, government subsidy on solar, operation hours increase due to reliable electricity.

Dependent Variable: Industrial growth due to solarization, operationalized through indicators such as production output, cost savings.

Control Variables: Industry size, sector type, geographical location, and access to financial incentives.

3.5 Data Analysis Techniques

The collected secondary data is analyzed using a combination of **statistical and econometric techniques** to assess the impact of solar energy adoption on industrial growth in Pakistan. Initially, Solar Energy adaption, government subsidy on solar, operation hours increase due to reliable electricity to summarize the data and illustrate trends in solar energy adoption across industrial sectors. Following this, **correlation analysis** is conducted to examine the strength and direction of relationships between solar energy adoption and key economic indicators such as Solar Energy adaption, government subsidy on solar, operation hours increase due to reliable electricity. To determine the effect of solar energy adoption on industrial performance while controlling for variables such as industry size, sector type, and geographical

location, **multiple linear regression models** are applied. Furthermore, adoption determinants, operational efficiency, and economic outcomes, drawing methodological guidance from studies like Kim et al. (2014) and Arias et al. (2025). This comprehensive analytical approach ensures robust evaluation of the economic impact of solar energy adoption on Pakistan’s industrial growth.

3.5 Data Analysis Techniques

The collected secondary data is analyzed using a combination of **statistical and econometric techniques** to evaluate the impact of solar energy adoption on industrial growth in Pakistan. Additionally, **multiple linear regression models** are applied to determine the effect of solar energy adoption on industrial performance while controlling for factors such as industry size, sector type, and geographic location. For assessing more complex relationships between adoption determinants, operational efficiency, and economic outcomes, **structural equation modeling (SEM)** is employed, following approaches from Kim et al. (2014) and Arias et al. (2025). This integrated analytical framework ensures a robust evaluation of the economic implications of solar energy adoption for Pakistan’s industrial sector.

Regression Statistics

| | |
|-------------------|---------|
| Multiple R | 0.99225 |
| R Square | 0.98455 |
| Adjusted R Square | 0.93821 |
| Standard Error | 2.0569 |
| Observations | 5 |

ANOVA

| | df | SS | MS | F | Significance F |
|------------|----|---------|---------|------|----------------|
| Regression | 3 | 269.641 | 89.8804 | 21.2 | 0.15784 |
| Residual | 1 | 4.23082 | 4.23082 | | |
| Total | 4 | 273.872 | | | |

Coefficients

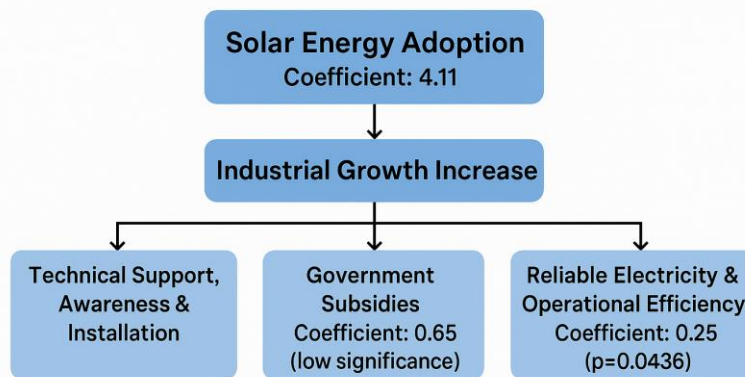
| | Coefficients | Standard Error | t Stat | P-value |
|--------------|--------------|----------------|---------|---------|
| Intercept | 3.49053 | 2.49443 | 1.39933 | 0.4 |
| X Variable 1 | 4.11482 | 5.62032 | 2.73213 | 0.06 |
| X Variable 2 | 0.64782 | 0.05002 | 1.29503 | 0.42 |
| X Variable 3 | 0.25375 | 0.20765 | 3.22202 | 0.04 |

Table.3.1

The regression analysis examined the relationship between the dependent variable (Industrial growth) and three independent variables (Solar energy adoption, , government subsidy on solar and operation hours increase due to reliable electricity). The model demonstrated a very strong fit, with Multiple R = 0.992, R² = 0.9846, and Adjusted R² = 0.9382, indicating that approximately 98% of the variation in Y is explained by the predictors. The Standard Error was 2.0569, reflecting the average distance of observed values from the regression line. Despite the high explanatory power, the overall model was not statistically significant (Significance F =

0.1578), likely due to the very small sample size (n = 5), which limits the reliability of the results. Among the predictors, operation hours increase due to reliable electricity (X3) had a positive and statistically significant effect on Y (p = 0.0437), Solar energy adoption, (X1) was marginally significant (p = 0.0598), and government subsidy on solar(X2) had a negligible and non-significant effect (p = 0.4186). The intercept was not significant (p = 0.3950), and the relatively wide confidence intervals for the coefficients indicate considerable uncertainty in the estimates. Overall, X3 emerged as the most reliable predictor, while the small sample size suggests caution in generalizing these findings.

Policy Recommendations to Promote Industrial Growth via Solar Energy



Policy Focus Areas: - Incentives - Targeted Subsidies - Stable Energy

4.1 Policy Recommendations Based on Regression Results

Based on the regression analysis, the model demonstrates a strong explanatory power (R² = 0.9846), indicating that the independent variables collectively have a substantial influence on industrial growth due to solar energy adoption. However, the limited number of observations (n = 5) reduces statistical significance, so the findings should be interpreted cautiously. Despite this limitation, the following policy recommendations can be drawn:

1. **Promote Solar Energy Adoption in Industries**
 Solar Energy adoption: The positive coefficient of solar energy adoption

suggests that industries implementing solar solutions are likely to experience significant growth. Policymakers should incentive the integration of solar energy through technical support, awareness campaigns, and subsidies for installation, especially for small- and medium sized enterprises.

2. **Strengthen Government Subsidies on Solar**
 Although the effect of government subsidies (0.65) is positive, it is statistically less significant. This indicates potential underutilization or insufficient targeting of subsidies. Policymakers should review subsidy allocation mechanisms, ensure timely disbursement, and prioritize sectors with high growth potential to maximize impact.

3. Enhance Operational Efficiency via Reliable Electricity :

The positive and significant impact of increased operation hours due to reliable electricity (0.25, $p = 0.0436$) highlights the importance of stable energy supply. Policies should focus on combining solar energy adoption with grid support to increase operational hours, reduce downtime, and enhance industrial productivity.

4. Integrated Policy Approach:

Since multiple factors jointly influence industrial growth, an integrated strategy combining solar adoption, targeted subsidies, and improved operational reliability will yield more sustainable results than isolated interventions.

5. Future Data Collection and Monitoring:

The high R^2 but limited significance underscores the need for larger datasets and continuous monitoring. Policymakers should invest in systematic data collection to validate these results and support evidence-based policy decisions.

Conclusion:

Implementing a comprehensive solar energy policy, supported by targeted subsidies and operational improvements, can significantly enhance industrial growth and sustainability. Continuous evaluation will ensure policies remain effective and adaptable to changing industrial needs.

REFERENCES

Jie, H., Khan, I., Alharthi, M., Zafar, M. W., & Saeed, A. (2023). Sustainable energy policy, socio-economic development, and ecological footprint: The economic significance of natural resources, population growth, and industrial development. *Utilities Policy*, 81, 101490.

Ajmair, M. (2014). Impact of industrial sector on GDP (Pakistan Case). *Eur. J. Cont. Econ. & Mgmt.*, 1, 106.

Ali, N., Butzbach, O. K., Katohar, H. A., & Afridi, H. I. (2024). Structural and External Barriers to Pakistan's Economic Growth: Pathways to Sustainable Development. *World*, 5(4), 1120-1129.

Mirza, U. K., Maroto-Valer, M. M., & Ahmad, N. (2003). Status and outlook of solar energy use in Pakistan. *Renewable and Sustainable Energy Reviews*, 7(6), 501-514.

Mekhilef, S., Saidur, R., & Safari, A. (2011). A review on solar energy use in industries. *Renewable and sustainable energy reviews*, 15(4), 1777-1790.

Mekhilef, S., Saidur, R., & Safari, A. (2011). A review on solar energy use in industries. *Renewable and sustainable energy reviews*, 15(4), 1777-1790.

Adanma, U. M., & Ogunbiyi, E. O. (2024). Assessing the economic and environmental impacts of renewable energy adoption across different global regions. *Engineering Science & Technology Journal*, 5(5), 1767-1793.

Bauner, C., & Crago, C. L. (2015). Adoption of residential solar power under uncertainty: Implications for renewable energy incentives. *Energy Policy*, 86, 27-35.

Kim, H., Park, E., Kwon, S. J., Ohm, J. Y., & Chang, H. J. (2014). An integrated adoption model of solar energy technologies in South Korea. *Renewable energy*, 66, 523-531.

Li, Z. (2024). Solar energy adoption on local economic growth: a linear regression study. *Highlights in Business Economics and Management*, 24, 263-271.

Andrade-Arias, A. S., Kabir, G., Mirmohammadsadeghi, M., Gunasekaran, A., & Elizondo-Noriega, A. (2025). Exploring public perspectives on solar energy adoption in Mexico. *Renewable and Sustainable Energy Reviews*, 212, 115410.

Graziano, M., Fiaschetti, M., & Atkinson-Palombo, C. (2019). Peer effects in the adoption of solar energy technologies in the United States: An urban case study. *Energy research & social science*, 48, 75-84.

- Adao, B., Narajabad, B., & Temzelides, T. (2024). Renewable technology adoption costs and economic growth. *Energy Economics*, 129, 107255.
- Santoso, N. P. L., Desrianti, D. I., Darmawan, D., Wahid, S. M., Fitriani, A., & Fauzi, A. Y. (2024, August). Optimizing solar energy adoption through technological and economic initiatives. In *2024 3rd International Conference on Creative Communication and Innovative Technology (ICCIIT)* (pp. 1-6). IEEE.
- Timilsina, G. R., Kurdgelashvili, L., & Narbel, P. A. (2012). Solar energy: Markets, economics and policies. *Renewable and sustainable energy reviews*, 16(1), 449-465.
- Bhutto, A. W., Bazmi, A. A., & Zahedi, G. (2012). Greener energy: issues and challenges for Pakistan—solar energy prospective. *Renewable and Sustainable Energy Reviews*, 16(5), 2762-2780.
- Mirza, U. K., Maroto-Valer, M. M., & Ahmad, N. (2003). Status and outlook of solar energy use in Pakistan. *Renewable and Sustainable Energy Reviews*, 7(6), 501-514.
- Irfan, M., Zhao, Z. Y., Ahmad, M., & Mukeshimana, M. C. (2019). Solar energy development in Pakistan: Barriers and policy recommendations. *Sustainability*, 11(4), 1206.
- Raza, M. Y., Wasim, M., & Sarwar, M. S. (2020). Development of Renewable Energy Technologies in rural areas of Pakistan. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 42(6), 740-760.
- Mirza, U. K., Ahmad, N., Harijan, K., & Majeed, T. (2009). Identifying and addressing barriers to renewable energy development in Pakistan. *Renewable and Sustainable Energy Reviews*, 13(4), 927-931.
- Akhtar, S., Hashmi, M. K., Ahmad, I., & Raza, R. (2018). Advances and significance of solar reflectors in solar energy technology in Pakistan. *Energy & Environment*, 29(4), 435-455.
- Irfan, M., Zhao, Z. Y., Rehman, A., Ozturk, I., & Li, H. (2021). Consumers' intention-based influence factors of renewable energy adoption in Pakistan: a structural equation modeling approach. *Environmental Science and Pollution Research*, 28(1), 432-445.
- Qureshi, T. M., Ullah, K., & Arentsen, M. J. (2017). Factors responsible for solar PV adoption at household level: A case of Lahore, Pakistan. *Renewable and Sustainable Energy Reviews*, 78, 754-763.
- Zafar, U., Rashid, T. U., Khosa, A. A., Khalil, M. S., & Rashid, M. (2018). An overview of implemented renewable energy policy of Pakistan. *Renewable and Sustainable Energy Reviews*, 82, 654-665.
- Awan, A. B., & Khan, Z. A. (2014). Recent progress in renewable energy—Remedy of energy crisis in Pakistan. *Renewable and Sustainable Energy Reviews*, 33, 236-253.
- Qamar, S., Ahmad, M., Oryani, B., & Zhang, Q. (2022). Solar energy technology adoption and diffusion by micro, small, and medium enterprises: sustainable energy for climate change mitigation. *Environmental Science and Pollution Research*, 29(32), 49385-49403.
- Shakeel, S. R., Takala, J., & Shakeel, W. (2016). Renewable energy sources in power generation in Pakistan. *Renewable and Sustainable Energy Reviews*, 64, 421-434.
- Mekhilef, S., Saidur, R., & Safari, A. (2011). A review on solar energy use in industries. *Renewable and sustainable energy reviews*, 15(4), 1777-1790.

Jabeen, M., Umar, M., Zahid, M., Rehaman, M. U., Batool, R., & Zaman, K. (2014). Socio-economic prospects of solar technology utilization in Abbottabad, Pakistan. *Renewable and Sustainable Energy Reviews*, 39, 1164-1172.

https://startuppakistan.com.pk/esl-renewables-private-limited-signs-contract-for-9-8mw-solar-power-plant-with-alkaram-textile-mills-bringing-total-plant-capacity-to-14mw/?utm_source=chatgpt.com

https://www.brecorder.com/news/40361845/pakistan-major-steel-maker-activates-64mw-solar-plant-at-karachi-plant?utm_source=chatgpt.com

<https://www.bestway.com.pk/https://reonenergy.com/projects/>

<https://www.ft.com/https://www.lucky-cement.com/>

<https://www.artisticmilliners.com/sustainability>

https://www.pv-magazine.com/2025/03/20/pakistans-net-metering-solar-capacity-surpasses-4-gw/?utm_source=chatgpt.com

https://www.afternic.com/forsale/dsgenergy.com?utm_source=TDFS_DASLNC&utm_medium=parked-pages&utm_campaign=x_corp_tdfs-daslnc_base&traffic_type=TDFS_DASLNC&traffic_id=daslnc&oref=https%3A%2F%2Fchatgpt.com%2F

<https://www.dgcement.com/>

<https://www.nishat.net/>

<https://reonenergy.com/projects/>

<https://www.pbs.gov.pk/content/quantum-index-manufacturing-qim-december-2024>

<https://data.worldbank.org/indicator/NV.IND.TO.TL.ZG?locations=PK>

https://www.ceicdata.com/en/indicator/pakistan/industrial-production-index-growth?utm_source=chatgpt.com

<https://www.reuters.com/world/asia-pacific/pakistans-economy-contracts-first-quarter-fy2024-25-2024-10-07/>

<https://www.reuters.com/markets/asia/pakistan-manufacturing-pmi-expands-april-2025-2025-05-03/>

<https://www.pbs.gov.pk/content/quantum-index-manufacturing-qim-december-2024>

<https://www.pbs.gov.pk/content/national-accounts-committee-revised-estimates-october-2025>

https://sleeksolar.com/solar-energy-a-game-changer-for-pakistans-industries/?utm_source=chatgpt.com

https://apexsolar.pk/from-5kw-to-50kw-how-businesses-are-saving-millions-with-solar-in-pakistan/?utm_source=chatgpt.com

https://soluxiaenergy.com/residential-solar-energy-savings-in-pakistan/?utm_source=chatgpt.com

https://dawamsolar.pk/solar-panels/solar-energy-pricing-cost-per-kwh-in-pakistan/?utm_source=chatgpt.com

https://www.pv-magazine.com/2025/03/20/pakistans-net-metering-solar-capacity-surpasses-4-gw/?utm_source=chatgpt.com

