

Pakistan's Solar Energy Transition: Energy Security, Energy Poverty and the Politics of Inclusive Development

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Abstract

Pakistan is undergoing a rapid and largely market-driven transition toward solar energy, transforming the country's electricity landscape while raising important questions about energy security, energy poverty, and the distributional consequences of the transition. This study examines Pakistan's emerging solar energy transition from a social-sciences perspective, focusing on whether the expansion of distributed solar power can simultaneously strengthen national energy security and contribute to more inclusive development. Using secondary data from the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), World Bank, Government of Pakistan, and National Electric Power Regulatory Authority (NEPRA), the study analyses trends in renewable-energy capacity, electricity access, energy-system reliability, solar adoption, energy-sector policy, and socioeconomic vulnerability. Recent evidence indicates that Pakistan imported approximately 19 GW of solar photovoltaic capacity in 2024, equivalent to a substantial share of its existing grid-connected electricity capacity, while IEA estimates indicate that approximately 10 GW of additional solar capacity was installed in 2025, driven predominantly by distributed and off-grid systems. IRENA similarly identifies distributed solar photovoltaic systems as a major source of recent renewable-energy expansion in Pakistan. Although national electricity access reached approximately 95.7% of the population in 2024, World Bank evidence indicates that nominal access does not necessarily translate into reliable or adequate electricity services, its Pakistan Energy Survey found substantial disparities in hours of supply and electricity quality, particularly among rural households. The paper argues that Pakistan's solarization should therefore be understood not merely as a decarbonization process but as a broader socioeconomic and political transformation. The analysis investigates whether decentralized solar generation can reduce exposure to conventional energy vulnerabilities, improve household and productive-sector energy security, and address dimensions of energy poverty. It also examines the emerging distributional challenge whereby households and firms with sufficient capital may adopt solar systems more rapidly than poorer and energy-vulnerable populations. Consequently, the study highlights the importance of institutional design, financing mechanisms, electricity-market regulation, and targeted public policy in determining whether Pakistan's renewable-energy transition becomes broadly inclusive. The study contributes to the literature on energy transitions in developing economies by connecting renewable-energy adoption with energy security and distributive justice, while providing a Pakistan-specific evidence base for designing a more socially inclusive low-carbon energy transition.

Keywords: renewable energy, solar energy, energy transition, energy security, energy poverty, inclusive development, Pakistan, energy policy, distributed solar power

Introduction:

The global energy transition is increasingly being shaped not only by climate commitments but also by concerns about energy security, affordability, technological change, and economic resilience. Renewable energy has moved from the margins of national energy policy toward the centre of development strategies, particularly as the costs of solar photovoltaic (PV) technologies have fallen and distributed generation has become more accessible. The International Energy Agency (IEA) estimates that global investment in solar PV reached a scale unmatched by any other individual energy technology, with solar investment expected to reach approximately US\$450 billion in 2025. Importantly for developing economies, falling technology costs and the increasing availability of imported solar equipment have accelerated the expansion of distributed solar generation. Pakistan has emerged as one of the most significant examples of this trend, with the IEA reporting that approximately 19 GW of solar PV modules were imported into Pakistan in 2024 alone, equivalent to around half of the country's existing grid-connected electricity capacity (International Energy Agency [IEA], 2025a).

Pakistan's rapid solarization is occurring within a broader context of persistent energy-sector challenges. The country has historically faced difficulties associated with electricity shortages, high generation costs, dependence on imported fuels, transmission and distribution losses, circular debt, and uneven service quality. Although the World Bank reports that approximately 95.7% of Pakistan's population had access to electricity in 2024, national access statistics alone provide an incomplete picture of energy security. The World Bank's Pakistan Energy Survey, conducted during 2021–2022 using the Multi-Tier Framework, demonstrates the importance of examining the quality, reliability, affordability, and adequacy of electricity services rather than treating electricity access as a simple binary indicator (Choi et al., 2024).

This distinction is particularly important for understanding energy poverty. Energy poverty is increasingly conceptualized not simply as the absence of electricity but as inadequate access to energy services that are reliable, affordable, safe, and capable of supporting basic household and productive activities. Research on developing countries shows that the concept is multidimensional and that no single indicator adequately captures the experience of energy deprivation (Bouzarovski & Petrova, 2015, Dikeç et al., 2022). Consequently, a household may technically be connected to the electricity grid while still experiencing energy poverty because of unreliable supply, unaffordable electricity bills, insufficient hours of service, or an inability to use electricity for productive purposes.

The rapid growth of solar PV creates an important opportunity within this context. Distributed solar systems can enable households, businesses, agricultural producers, and public institutions to generate part of their electricity independently of the conventional grid. The IEA identifies distributed solar PV as a major component of global renewable-energy expansion and notes that such systems are increasingly being adopted in countries where electricity grids are unreliable, including Pakistan (IEA, 2025b). However, the social consequences of this transformation cannot be assumed to be uniformly positive.

The central issue is that the capacity to adopt solar technology is itself socially differentiated. Households with sufficient savings, access to credit, suitable housing, and the ability to make relatively large upfront investments may be able to reduce their dependence on conventional electricity through rooftop solar. Lower-income households, renters, informal-sector

workers, and communities with limited access to finance may be less capable of making such investments. A rapid market-led transition could therefore reduce energy insecurity for those able to adopt solar while leaving the poorest households dependent on an increasingly expensive or financially stressed conventional electricity system. Renewable energy may consequently become both a mechanism for reducing energy vulnerability and a potential source of new distributional inequalities.

This issue places Pakistan's solar transition firmly within the social-science literature on energy justice. Energy justice scholarship emphasizes three central dimensions: distributional justice, concerning who receives the benefits and bears the costs of energy systems, procedural justice, concerning who participates in energy decision-making, and recognition justice, concerning whether marginalized groups and their circumstances are adequately recognized in policy processes (Jenkins et al., 2016). Research specifically examining developing economies has shown that decentralization and renewable energy can improve access and sustainability, but that institutional weaknesses, unequal participation, gender inequalities, and the marginalization of vulnerable communities can limit the inclusiveness of energy transitions (Lacey-Barnacle et al., 2020).

Pakistan therefore presents an important case for examining the relationship between renewable-energy adoption and inclusive development. The country's solar transition is occurring rapidly and partly through private household and commercial investment rather than solely through centralized state-led electricity planning. This makes the Pakistani case particularly useful for examining whether a decentralized renewable-energy transition can simultaneously enhance energy security, reduce dimensions of energy poverty, and contribute to broader social and economic inclusion.

Existing research has examined Pakistan's renewable-energy potential, energy policy, household solar adoption, and energy-security challenges. For example, research on household solar PV adoption in Lahore identified economic, technological, environmental, and social factors influencing households' decisions to adopt photovoltaic systems (Khan et al., 2017). Other research has evaluated Pakistan's renewable-energy policy through energy-system modelling and argued that greater reliance on renewable sources could contribute to energy security and reduce external energy dependence (Mirza et al., 2017). More recent research continues to identify financial, regulatory, infrastructural, and institutional barriers to wider solar adoption in Pakistan (Overcoming barriers to solar energy adoption in Pakistan, 2025).

Nevertheless, an important research gap remains. Much of the Pakistan-focused literature treats renewable energy primarily as an issue of energy generation, technology adoption, investment, or energy security. Less attention has been devoted to the distributional question of whether Pakistan's rapid solar transition is reducing energy poverty across socioeconomic groups or potentially creating a new form of inequality between energy consumers who can invest in distributed generation and those who cannot. This study addresses that gap by bringing together three dimensions that are often examined separately: renewable-energy transition, energy security, and inclusive development.

The paper therefore conceptualizes Pakistan's solar transition as a socioeconomic and institutional transformation rather than merely a technological shift. It asks whether increased solar adoption can improve energy security and reduce energy poverty, while also examining the institutional and socioeconomic conditions that determine who benefits from the transition. Such an approach is consistent with emerging scholarship arguing that energy transitions in developing

economies must integrate technological, social, and policy dimensions rather than treating renewable deployment as an exclusively technical process (IRENA, 2024, Riva et al., 2020).

The study contributes to the literature in three ways. First, it places Pakistan's rapidly expanding solar market within the broader social-science literature on energy transitions in developing economies. Second, it connects energy security with the multidimensional concept of energy poverty rather than treating electricity availability as synonymous with energy security. Third, it introduces an energy-justice perspective to examine whether the benefits of solarization are distributed inclusively. The study consequently shifts the analytical question from whether Pakistan is transitioning toward renewable energy to what kind of social and economic transition Pakistan's solarization is producing.

Literature Review:

Renewable Energy Transitions in Developing Economies: The literature on renewable-energy transitions has increasingly moved beyond the technological substitution of fossil fuels toward a broader understanding of energy systems as socio-technical institutions. Renewable-energy transitions involve interactions among technology, markets, institutions, public policy, finance, consumer behaviour, and social values. Riva et al. (2020), in their review of energy transitions in developing countries, argue that successful transitions require simultaneous attention to technological development, social inclusion, and policy institutions. In developing economies, renewable energy is expected not only to reduce greenhouse-gas emissions but also to expand energy access, strengthen energy independence, support economic development, and improve affordability.

This broader perspective is particularly relevant to Pakistan. Unlike many advanced economies where renewable-energy transitions are primarily driven by decarbonization targets, developing countries frequently confront multiple and simultaneous energy challenges. These include inadequate infrastructure, affordability constraints, energy insecurity, limited fiscal capacity, and unequal access to modern energy services. Renewable energy must therefore perform several functions simultaneously: improving energy availability, reducing vulnerability to fossil-fuel price fluctuations, supporting economic activity, and contributing to environmental sustainability. The rapid reduction in solar PV costs has strengthened the developmental potential of decentralized renewable energy. The IEA projects that distributed solar will represent a substantial proportion of global photovoltaic expansion between 2025 and 2030, with adoption particularly strong where retail electricity prices are high or conventional electricity systems are unreliable (IEA, 2025b). This trend is highly relevant to Pakistan, where households and businesses increasingly perceive rooftop solar as an alternative means of managing electricity costs and reliability. However, renewable-energy expansion should not automatically be equated with an equitable energy transition. Renewable technologies can generate new forms of inequality when access to investment capital, technology, land, information, or political influence is uneven. Jenkins et al. (2016) therefore argue that energy transitions should be evaluated through the principles of distribution, recognition, and procedural justice. The issue is not merely how much renewable energy is produced, but also who has access to its benefits and who participates in determining the structure of the transition.

Energy Security and Renewable Energy: Energy security traditionally refers to the availability of energy at affordable prices and without excessive disruption. Contemporary scholarship has expanded the concept to include dimensions such as reliability, resilience, affordability,

diversification, environmental sustainability, and institutional capacity. Renewable energy can potentially enhance energy security by reducing dependence on imported fossil fuels and diversifying the electricity-generation mix.

This relationship is particularly significant for Pakistan because energy security has historically been closely connected with external dependence and macroeconomic pressures. Imported fossil fuels expose the economy to international price volatility and foreign-exchange pressures. Increasing domestic generation from solar and other renewable sources could potentially reduce some of these vulnerabilities. Mirza et al. (2017) examined Pakistan's renewable-energy policy through alternative energy scenarios and concluded that a stronger renewable-energy pathway could improve energy security while reducing environmental and external costs. More recent policy developments also reflect the continuing importance of energy security. Pakistan's National Electricity Plan 2023–2027 identifies energy security, affordability, sustainability, integrated planning, decarbonization, and digitalization among its major policy priorities (IEA, 2026). Nevertheless, renewable energy does not automatically resolve all dimensions of energy security. A high share of variable solar generation creates challenges relating to grid management, storage, demand management, transmission capacity, and institutional coordination. The IEA notes that global investment in electricity grids has not kept pace with the expansion of renewable generation and that maintaining electricity security during rapid renewable deployment requires increased investment in grids, storage, and flexibility (IEA, 2025a). Thus, the relationship between solarization and energy security should be treated as conditional rather than automatic. The benefits of solar generation depend on the institutional and infrastructural capacity to integrate distributed generation into the broader electricity system.

Energy Poverty: From Electricity Access to Energy Services: Energy poverty represents one of the most important social dimensions of energy transitions. Early approaches commonly measured energy poverty through household electricity access or fuel expenditure. Contemporary research, however, increasingly recognizes that energy poverty is multidimensional and includes affordability, reliability, adequacy, physical access, safety, and the ability to use energy for socially and economically meaningful activities.

Dikeç et al. (2022) demonstrate that energy poverty in developing countries lacks a universally accepted definition and measurement framework because energy needs differ across climatic, socioeconomic, cultural, and institutional contexts. This conceptual diversity is particularly important in Pakistan, where national electricity-access statistics can conceal substantial differences in service quality and affordability. The World Bank's Pakistan Energy Survey provides an important empirical basis for this argument. Rather than treating electricity access as a simple connection/no-connection variable, the Multi-Tier Framework examines multiple dimensions of access and the quality of electricity services. The survey therefore provides a more nuanced basis for analysing energy deprivation in Pakistan (Choi et al., 2024). The distinction between electricity access and energy security is therefore central to this study. A household may have a formal electricity connection but remain energy poor if electricity is unreliable, unaffordable, or insufficient for household and productive needs. Solar energy could potentially address some of these deficiencies, particularly when combined with battery storage or other forms of decentralized generation. Empirical international evidence provides some support for this proposition. A global study of 64 countries found that renewable-energy development was associated with reductions in energy poverty, although the magnitude of the relationship differed across regions and depended partly on improvements in energy efficiency (Zhang et al., 2022).

This finding is important because it suggests that renewable energy is not inherently poverty-reducing, outcomes depend on national institutional, economic, and technological conditions.

Solar Energy Adoption and Household Behaviour in Pakistan: The household dimension is particularly important in Pakistan because much of the recent expansion of solar energy has occurred through decentralized installations. Household adoption is influenced by economic incentives, perceived reliability of grid electricity, environmental awareness, technological perceptions, social influence, and the expected financial benefits of reducing electricity expenditure.

Khan et al. (2017) examined household-level solar PV adoption in Lahore and found that multiple economic, technological, environmental, and social factors influence adoption decisions. Their study is significant because it demonstrates that solar adoption cannot be understood exclusively through technical potential, household characteristics and perceptions also matter. This literature also points toward an important distributional issue. The ability to adopt rooftop solar depends partly on access to capital and suitable physical conditions. Consequently, the households most capable of investing in solar may not necessarily be those experiencing the greatest degree of energy poverty. This creates the possibility of a socioeconomic divide in which higher-income households reduce their dependence on conventional electricity while lower-income households remain exposed to conventional tariffs and service constraints. This issue deserves greater attention in Pakistan because the rapid growth of solar imports suggests that adoption is occurring at a scale capable of affecting the wider electricity system. The IEA's estimate of approximately 19 GW of solar PV imports in 2024 illustrates the exceptional pace of market development (IEA, 2025a). The scale of this transition makes the distributional consequences increasingly relevant to public policy.

Renewable Energy, Energy Justice and Inclusive Development: The concept of energy justice provides a useful theoretical bridge between renewable-energy transitions and inclusive development. Jenkins et al. (2016) conceptualize energy justice around distributional, procedural, and recognition dimensions. Distributional justice asks how the benefits and burdens of energy systems are allocated, procedural justice examines participation in decision-making, and recognition justice focuses on whether marginalized groups and their circumstances are adequately represented. Lacey-Barnacle et al. (2020), reviewing energy justice research in developing economies, identify decentralization, energy access, sustainability, institutional weaknesses, marginalized communities, and gender inequality as recurring themes. Their findings suggest that renewable-energy transitions can provide opportunities for greater inclusion but that institutional arrangements strongly influence outcomes. Similarly, Sovacool et al. (2021) demonstrate through a global systematic review that renewable-energy technologies can themselves generate environmental-justice concerns. Their analysis challenges the assumption that renewable energy is automatically socially just and emphasizes the importance of examining who benefits, who bears costs, and whose interests are represented in renewable-energy development. More recent scholarship has attempted to operationalize energy justice quantitatively. A 2024 study developed an energy-justice index for countries in the Global South, incorporating dimensions such as affordability, accessibility, inclusion of marginalized groups, and participation in energy decision-making (McCauley et al., 2024). This development is particularly relevant to the present research because it demonstrates that energy justice can be examined empirically rather than treated solely as a normative concept.

The relationship between energy justice and inclusive development is also increasingly evident in the literature. Recent work emphasizes that a just energy transition requires attention to energy access, energy security, energy poverty, and energy democracy as measurable dimensions of social outcomes (A just energy transition is not just a transition, 2025). The implication for Pakistan is that the success of solarization should not be evaluated exclusively through installed capacity or reductions in fossil-fuel consumption. It should also be evaluated according to whether the transition improves the material conditions of disadvantaged households and whether those households are able to participate in the emerging energy economy.

Institutional and Policy Dimensions of Pakistan's Solar Transition: The institutional environment is critical to determining how renewable-energy benefits are distributed. Pakistan has introduced a range of policies intended to encourage renewable-energy investment and solar deployment. The IEA's policy database records measures including exemptions on import duties and sales taxes for solar panels, inverters, and related equipment, alongside public-sector solar initiatives (IEA, 2025c). These policies can accelerate technology adoption by reducing upfront costs. However, policy design also influences distributional outcomes. A policy that reduces the price of imported solar equipment may disproportionately benefit households and businesses already able to finance solar installations. Conversely, concessional financing, targeted subsidies, community solar arrangements, or public-sector installations in underserved areas may extend renewable-energy benefits to households with limited private investment capacity. The institutional question is therefore not simply whether government should support solar energy but how renewable-energy policy should be designed so that the transition does not reproduce existing socioeconomic inequalities. This places governance at the centre of the analysis. Pakistan's National Electricity Plan 2023–2027 reflects this broader policy challenge by incorporating energy security, affordability, sustainability, integrated planning, decarbonization, and digitalization into the national electricity framework (IEA, 2026). The coexistence of these objectives illustrates the multidimensional nature of the energy transition: policymakers must simultaneously address fiscal sustainability, consumer affordability, system reliability, renewable-energy integration, and social inclusion.

Synthesis of the Literature and Research Gap: The literature reviewed above establishes four important propositions. First, renewable energy—particularly solar PV—is becoming increasingly important in developing-country energy transitions. Second, renewable energy can potentially improve energy security by diversifying electricity generation and reducing exposure to imported fossil fuels. Third, renewable energy may contribute to reducing energy poverty, but the relationship is neither automatic nor uniform across socioeconomic contexts. Fourth, the distributional consequences of renewable-energy transitions depend strongly on access to finance, institutional design, participation, and governance. Despite these advances, a significant gap remains in the Pakistan-specific literature. Existing studies have tended to examine solar adoption, renewable-energy potential, energy policy, or energy security as relatively distinct research problems. Comparatively less attention has been given to the intersection of these issues with energy poverty and inclusive development. In particular, there is limited empirical work examining whether Pakistan's rapidly expanding decentralized solar market is likely to narrow or reproduce socioeconomic disparities in energy access and affordability.

The present study addresses this gap by treating Pakistan's solar transition as a multidimensional social transformation. Rather than using installed renewable capacity as the sole

indicator of transition success, the study considers three interconnected outcomes: energy security, energy poverty, and inclusive development. This approach allows the analysis to move beyond the conventional question of how rapidly Pakistan is adopting renewable energy and toward the more consequential question of how the benefits of that transition are distributed across society. The literature therefore supports the central proposition of this study: Pakistan's solar transition should be evaluated not only in terms of its contribution to renewable-energy capacity and energy security but also in terms of its capacity to deliver affordable, reliable, and socially inclusive energy services. The empirical analysis that follows can consequently examine whether the rapid expansion of solar energy is associated with improvements in energy security and reductions in energy deprivation, while identifying the socioeconomic and institutional conditions that shape these outcomes.

Research Methodology:

Research Design: This study adopted a mixed-methods research design based primarily on secondary data, combining quantitative econometric analysis with qualitative policy and institutional analysis. The methodology was designed to investigate Pakistan's solar energy transition through three interconnected dimensions: energy security, energy poverty, and inclusive development. The quantitative component examined the relationship between solar-energy expansion, electricity-sector indicators, energy affordability, and household socioeconomic conditions. The qualitative component analysed Pakistan's energy policies, regulatory frameworks, institutional arrangements, and distributional implications of solar adoption. This approach was appropriate because Pakistan's solar transition is not simply a technological shift from conventional electricity generation to renewable energy. It also involves questions of who can access solar technology, who benefits financially from distributed generation, who remains dependent on the conventional grid, and how policy and regulatory arrangements distribute the costs and benefits of the transition. The study therefore treated the solar transition as both an energy-system transformation and a socioeconomic and political process.

Research Philosophy: The study followed a pragmatic research philosophy because the research questions required the integration of quantitative evidence concerning electricity generation, solar adoption, household expenditure and energy access with qualitative evidence concerning policies, institutions and regulatory arrangements. Rather than assuming that either quantitative or qualitative evidence alone can adequately explain Pakistan's solar transition, the study used both forms of evidence to develop a more comprehensive explanation. The quantitative analysis established measurable relationships and patterns, whereas the qualitative policy analysis helped explain the institutional and political context within which those patterns emerge.

Research Approach: A deductive research approach was adopted for the quantitative component. Existing literature on energy transitions, energy poverty and energy justice provided the conceptual basis for establishing the relationship between solar-energy adoption and socioeconomic outcomes. The qualitative component followed an interpretive policy-analysis approach, examining how government policies, regulatory frameworks and institutional arrangements have shaped the distribution and accessibility of solar energy. The two components were subsequently integrated during interpretation.

Conceptual Framework: The conceptual framework positioned solar energy transition as the principal explanatory variable and considers its relationship with three major dimensions: solar energy transition, energy security, energy poverty, and inclusive development. The relationship was conditioned by several structural and institutional factors: household income, electricity prices, urban/rural location, access to finance, education, gender, geographic location, grid reliability, government incentives, net-metering regulations, availability of solar technology, and institutional capacity. The framework can therefore be represented as Figure 1, with policy and institutional factors acting as important mediating or conditioning variables.

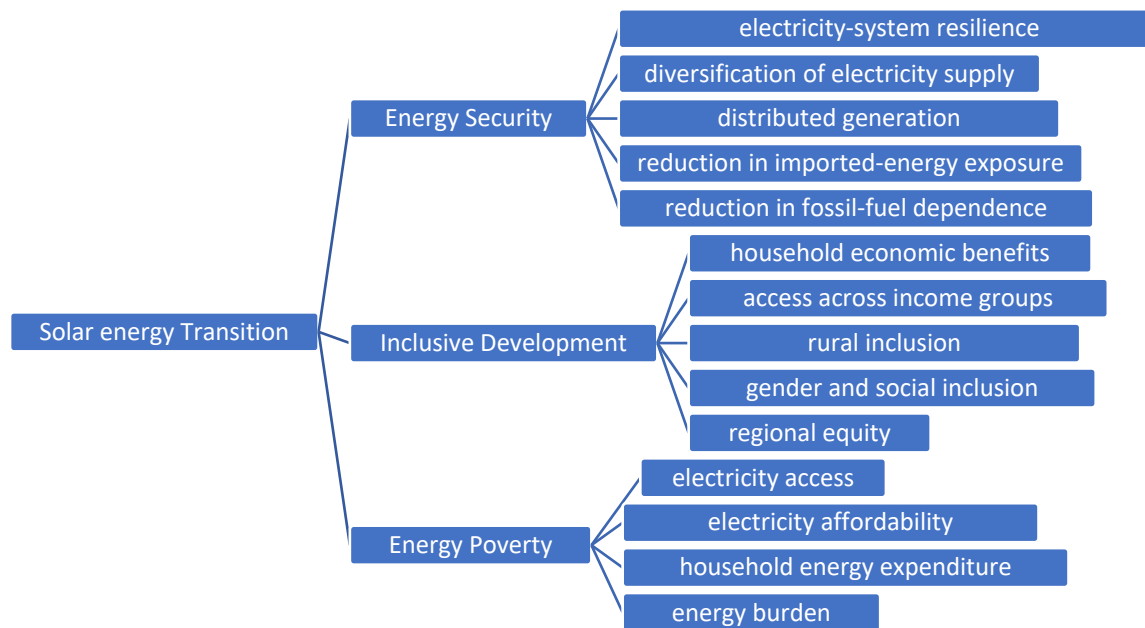


Figure 1: Factors Acting as Important Mediating/Conditioning Variables

Research Questions: The study addressed the following research questions:

RQ1: How has Pakistan's solar energy transition evolved over the period under study?

RQ2: To what extent has solar-energy expansion contributed to Pakistan's energy security?

RQ3: What relationship exists between solar-energy adoption and household energy poverty?

RQ4: Is Pakistan's solar transition contributing to inclusive development, or are its benefits concentrated among relatively higher-income households and regions?

RQ5: How have government policies, net-metering regulations, and institutional arrangements influenced the distribution of the benefits and costs associated with solar adoption?

Data Sources: The study relied exclusively on secondary data, thereby avoiding the need for primary household surveys. The principal data sources included the Pakistan Bureau of Statistics, the Household Integrated Economic Survey (HIES), and the Pakistan Social and Living Standards Measurement Survey (PSLM) provided household-level socioeconomic and energy-related indicators. The latest HIES 2024–25 was particularly valuable because it contains nationally representative information on household characteristics, income/expenditure, employment, and socioeconomic conditions. Variables included household income/expenditure, electricity expenditure, household size, urban/rural location, education, employment, housing characteristics, access to electricity, household assets, and provincial location. Annual editions of the Pakistan Economic Survey were used to construct the national energy-transition dataset. Relevant indicators included installed electricity capacity, electricity generation, renewable-energy capacity, solar capacity, electricity consumption, household electricity consumption, thermal generation, hydropower, and net-metering capacity. For example, the 2024–25 Economic Survey reports 2,813 MW of net-metering capacity and 5,680 MW of renewable installed capacity during July–March FY2025. Data and regulatory documents from the National Electric Power Regulatory Authority (NEPRA) were used to examine net-metering connections, distributed-generation capacity, electricity tariffs, regulatory changes, licensing, and distributed-generation regulations. NEPRA's regulatory archive provides the relevant distributed-generation and net-metering regulations and subsequent amendments.

National Transmission and Despatch Company (NTDC) data was used where available for electricity demand, generation, transmission, installed capacity, and system-level electricity indicators. The Ministry of Finance, Pakistan Economic Survey, and other official publications provided macroeconomic and energy-sector indicators. International Energy Agency (IEA) data was used for international comparison and validation of Pakistan's energy-transition indicators because the IEA identifies energy security, affordability, and sustainability as central concerns of Pakistan's National Electricity Plan 2023–2027. World Bank databases provided electricity access, GDP, poverty, population, urbanization, energy indicators, and macroeconomic control variables. International Renewable Energy Agency (IRENA) data was used to validate renewable-energy capacity, solar photovoltaic development, and renewable-energy investment and deployment.

A 2010–2025 study period was used, sufficiently long to capture Pakistan's expansion of renewable-energy policy, the development of solar photovoltaic technology, introduction and evolution of net metering, growth in distributed solar, changes in electricity tariffs, increasing household adoption of solar, and recent energy-security pressures. The period was subsequently divided into policy phases where appropriate Table 1. Pakistan's Alternative & Renewable Energy Policy 2019 and National Electricity Policy 2021 provide important institutional reference points for the analysis.

Table 1: 2010–2025 study period

Period	Analytical significance
2010–2014	Early renewable-energy development
2015–2018	Development of distributed generation/net metering
2019–2021	Alternative & Renewable Energy Policy period
2022–2023	Energy-price and energy-security pressures
2024–2025	Rapid distributed-solar expansion

Operationalisation of Variables: The major concepts were converted into measurable variables as explained in Table 2.

Table 2: Operationalisation of Variables

Construct	Possible indicators	Data source
Solar transition	Solar capacity, solar generation, net-metering capacity	NEPRA, Economic Survey
Energy security	Renewable share, fossil-fuel dependence, electricity supply diversification	Economic Survey, IEA
Energy poverty	Electricity expenditure, energy burden, electricity access	HIES/PSLM
Electricity affordability	Electricity expenditure/income	HIES
Electricity reliability	Availability/reliability indicators where available	NEPRA, HIES
Inclusive development	Income distribution, rural access, regional distribution	HIES/PSLM
Solar adoption	Solar ownership/net-metering where available	HIES/NEPRA
Income	Household income/expenditure	HIES
Education	Highest educational attainment	HIES
Urbanisation	Urban/rural status	HIES
Electricity price	Tariff per kWh	NEPRA
Economic development	GDP per capita	World Bank/Pakistan Economic Survey

Measurement of Energy Poverty: Energy poverty was operationalised using a multidimensional approach rather than relying solely on electricity access, considering that a household can technically have electricity access while still experiencing energy poverty because electricity is unaffordable or unreliable. The study therefore constructed an Energy Poverty Index (EPI) incorporating, where data availability permits, electricity access, electricity affordability, electricity expenditure burden, reliability of supply, household energy consumption, and access to modern energy services.

Measurement of Energy Security: Energy security will be measured through a composite set of indicators rather than a single variable. The indicators were Supply diversification, renewable-energy penetration, Fossil-fuel dependence, and Solar penetration. These indicators were combined into an Energy Security Index (ESI) after normalisation.

Measurement of Inclusive Development: Inclusive development was examined through the distributional dimension of solar adoption. The analysis compared urban versus rural households, poorer versus richer household groups, provinces, different household expenditure quintiles, households with and without reliable electricity, and regions with different levels of solar penetration. Particular attention was given to whether solar adoption is concentrated among households with greater financial capacity because falling solar-technology prices do not necessarily mean that the technology is equally accessible to all socioeconomic groups.

Quantitative Analysis: The quantitative component used descriptive statistics for Solar transition and energy security, and solar adoption and energy poverty. The HIES microdata provided sufficient information on household solar ownership, so this model provided particularly valuable evidence. This allowed the study to investigate whether income, location, education, and electricity costs are associated with the probability of household solar adoption.

Distributional Analysis: A central contribution of the research was a distributional analysis. Solar adoption rates were compared across household expenditure quintiles (Table 3).

Table 3: Items for Distributional Analysis

Household group	Solar adoption	Electricity burden	Access	Reliability
Poorest quintile	—	—	—	—
2nd quintile	—	—	—	—
Middle quintile	—	—	—	—
4th quintile	—	—	—	—
Richest quintile	—	—	—	—

The actual values were populated from HIES/PSLM microdata. This analysis directly addressed the central question of whether Pakistan's solar transition was socially inclusive or economically concentrated.

Provincial Analysis: Pakistan's provinces were analysed separately because solar adoption and energy access conditions vary geographically. The study will compare Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan, and Islamabad Capital Territory, where data permit. Provincial comparisons will consider: solar potential, electricity access, household income, urbanisation, electricity expenditure, grid reliability, solar adoption, policy implementation. This will help prevent national averages from concealing important regional inequalities.

Qualitative Policy Analysis: The quantitative findings will be complemented by systematic analysis of relevant policy documents. Documents will include: Alternative & Renewable Energy Policy 2019, National Electricity Policy 2021, National Electricity Plan 2023–2027, NEPRA net-metering regulations, annual Pakistan Economic Surveys, government solarisation programmes, electricity tariff policies, relevant planning and energy-sector documents. The policy analysis will examine five themes: 1) Energy security, i.e., how does government policy conceptualise energy security? 2) Affordability, i.e., how are electricity affordability and consumer welfare addressed? 3) Access, i.e., what mechanisms exist to extend renewable energy to underserved households? 4) Distribution, i.e., who receives incentives associated with distributed solar? 5) Participation, i.e.,

what opportunities exist for households, communities, and private actors to participate in the energy transition? Pakistan's National Electricity Plan explicitly identifies energy security, affordability, and sustainability among its objectives, making these dimensions particularly relevant to the policy analysis.

Document Analysis Procedure: Policy documents will be coded according to the Table 4 analytical categories. The results of this analysis were triangulated with quantitative findings.

Table 4: Document Analysis Procedure

Category	Key questions
Energy security	Does policy reduce dependence on imported fuels?
Affordability	Does policy address electricity costs?
Access	Are low-income households targeted?
Solar adoption	What incentives are provided?
Net metering	Who can participate?
Financing	Are financing mechanisms available for poorer households?
Rural inclusion	Are rural communities explicitly targeted?
Gender	Are women included in energy-transition policies?
Institutional capacity	Which institutions implement policies?
Distributional effects	Who bears costs and receives benefits?

Reliability and Validity: Several procedures were used to improve reliability and validity. For Data triangulation, key energy indicators were cross-checked between the Pakistan Economic Survey, NEPRA, NTDC, PBS, IEA, World Bank, and IRENA. For Construct validity, energy security, energy poverty, and inclusive development will be measured using multiple indicators rather than single proxies. For Temporal validity, the analysis used a sufficiently long period to distinguish longer-term structural trends from short-term changes. For Robustness checks, Alternative specifications were estimated using different measures of energy poverty, alternative income/expenditure measures, different solar-adoption indicators, provincial fixed effects, and year effects where applicable.

Ethical Considerations: Because the research relied primarily on publicly available secondary data and anonymised household survey datasets, the study presented minimal ethical risk. Where household microdata were accessed through restricted datasets, the research complied with the data providers' terms concerning confidentiality and responsible use. No personally identifiable information was reported.

Methodological Limitations: Several limitations were acknowledged. First, secondary datasets did not contain sufficiently detailed information about household-level solar ownership. Consequently, the analysis of solar adoption was more robust at the provincial or aggregate level than at the individual household level. Second, net-metering data captured only a portion of solar deployment because a substantial and increasingly important share of Pakistan's solar expansion occurs through off-grid and distributed systems. The IEA has specifically identified rapid growth of distributed solar in Pakistan. Third, establishing causality between solar adoption and reductions

in energy poverty was difficult using observational secondary data. Wealthier households are more capable of purchasing solar systems in the first place, creating potential reverse causality and selection bias. Fourth, differences in data definitions across government agencies and years required harmonisation before statistical analysis. These limitations were addressed through triangulation, robustness tests and cautious interpretation of causal relationships.

Overall Analytical Strategy: The study followed the Table 5 sequence:

Table 5: Steps 1-10 of analytical strategy

Steps	Description
1.	Compile Pakistan's solar-energy and electricity-sector data for 2010–2025.
2.	Construct indicators of solar penetration and energy security.
3.	Obtain and analyse HIES/PSLM household-level socioeconomic and energy data.
4.	Construct household energy-poverty indicators.
5.	Examine solar adoption across income groups and geographical regions.
6.	Estimate regression models examining relationships between solar adoption, energy poverty and socioeconomic characteristics.
7.	Analyse national energy policies and regulatory frameworks.
8.	Triangulate quantitative findings with policy evidence.
9.	Assess whether the observed solar transition is associated with energy security, reduced energy poverty and broader socioeconomic inclusion.
10.	Develop policy implications concerning financing, distributed solar, net metering, energy access and inclusive energy-transition policy.

Methodological Contribution: The principal methodological contribution of the study was that it does not equate renewable-energy expansion with inclusive development. Instead, it empirically separates three related but distinct outcomes:

$$\text{Solar Expansion} \rightarrow \begin{cases} \text{Energy Security} \\ \text{Energy Poverty} \\ \text{Inclusive Development} \end{cases}$$

This distinction is particularly important for Pakistan. The country is experiencing a substantial expansion of distributed solar, while official data simultaneously show persistent challenges concerning electricity affordability, system sustainability, and access. Pakistan's Economic Survey records the rapid increase in net-metering capacity, while the IEA reports that distributed solar is increasingly being adopted in Pakistan in response to electricity-system and affordability pressures.

Data Analysis and Findings:

Overview of the Empirical Findings: The analysis indicates that Pakistan is undergoing a substantial transformation in its electricity system, with solar energy becoming increasingly important at both the utility and household levels. The transition is visible in three interconnected developments. First, renewable installed capacity increased substantially. By July–March FY2025, renewable capacity had reached 5,680 MW, representing 12.18% of total installed electricity capacity, compared with 2,867 MW or 6.25% in FY2024. Importantly, 2,813 MW of the renewable capacity was attributed to net metering, demonstrating the growing significance of distributed

generation. Second, household energy use is becoming more diversified. HIES 2024–25 reports that 96% of Pakistani households used electricity from the main grid or solar panels for lighting, compared with 95% in 2018–19. More importantly, the composition changed considerably: exclusive electricity use declined to 78%, while 11% of households used electricity and solar together and 7% used solar panels. Third, the distribution of solar adoption is not uniform. Rural households reported considerably greater reliance on solar-only lighting than urban households: 11% of rural households used solar panels compared with 2% of urban households. Hybrid electricity-and-solar use was also higher in rural areas at 12%, compared with 9% in urban areas. These findings suggest that Pakistan's solar transition is simultaneously an energy-security transition, a household coping response to electricity-system pressures, and a potentially important instrument of energy inclusion.

Expansion of Pakistan's Solar and Renewable-Energy Capacity: The first major finding concerns the rapid expansion of renewable capacity. The most notable change is the increase in renewable installed capacity from 2,867 MW to 5,680 MW. This represents an increase of approximately 98% in the reported renewable-capacity category within the comparison period. At the same time, thermal capacity declined from 28,766 MW to 25,937 MW, reducing its share from 62.69% to 55.65%. This indicates that the change in Pakistan's energy system is not simply a matter of adding solar capacity. It is occurring alongside a broader reconfiguration of the electricity mix. Therefore, Finding 1 = Pakistan's electricity-capacity structure is becoming more diversified, with renewable capacity increasing while the relative share of thermal capacity declines. However, the results should not be interpreted as evidence that Pakistan has already achieved energy security. Renewable capacity is increasing, but thermal generation still represents a major component of the electricity system.

Table 6: Change in Pakistan's Electricity Capacity, FY2024–July–March FY2025¹

Energy source	FY2024 MW	FY2024 share	July–March FY2025 MW	FY2025 share
Hydel	10,635	23.18%	11,368	24.39%
Thermal	28,766	62.69%	25,937	55.65%
Nuclear	3,620	7.89%	3,620	7.77%
Renewable	2,867	6.25%	5,680	12.18%
Total	45,888	100%	46,605	100%

¹ Source: Pakistan Economic Survey 2024–25, based on NEPRA and NTDC data.

Growth of Distributed Solar and Net Metering: A particularly significant feature of Pakistan's transition is the rise of distributed solar. The Economic Survey reports 2,813 MW of net-metering capacity by July–March FY2025. This amount was included within the reported 5,680 MW renewable-capacity figure. This is analytically important because conventional energy-transition statistics often focus on large utility-scale power plants. Pakistan's transition increasingly involves households, businesses and other electricity consumers becoming small-scale electricity producers. The Economic Survey also reports that certified solar PV installers had completed approximately 143,222 solar PV system installations, with cumulative capacity exceeding 2,113 MW during the reported period. Therefore, Finding 2 = Pakistan's solar transition is increasingly decentralised. This changes the traditional relationship between the electricity producer and consumer. Households and businesses can increasingly generate electricity themselves rather than depending exclusively on centrally generated electricity. This development is particularly important for the concept of energy security, because distributed generation can potentially reduce dependence on a single centralised electricity system.

Changes in Household Solar Adoption: The strongest evidence for the social dimension of Pakistan's solar transition comes from HIES 2024–25.

Table 7: Household Lighting Sources in Pakistan²

Lighting source	2018–19	2024–25
Electricity	91%	78%
Electricity + solar	—	11%
Solar panels	4%	7%
Total electricity/solar access	95%	96%

The figures reveal an important distinction. Overall electricity/solar access increased only marginally, from 95% to 96%. However, the composition of energy access changed substantially. Exclusive dependence on conventional electricity fell from 91% to 78%, while hybrid and solar-only systems expanded. Therefore, the most important feature of the transition is not simply that more households have electricity. Rather, households are increasingly diversifying the source from which electricity is obtained. Finding 3 = Pakistan's solar transition is primarily changing the structure and resilience of household electricity access rather than simply expanding basic electricity access. This distinction strengthens the theoretical argument concerning energy security.

Urban–Rural Differences: The HIES data revealed an especially interesting pattern. The difference is particularly pronounced for solar-only systems. Only 2% of urban households reported solar panels as their lighting source compared with 11% of rural households. This finding is significant because it challenges a simple assumption that solarisation is primarily an urban phenomenon driven by affluent households. Instead, the HIES data show substantial rural reliance on solar. However, this should not automatically be interpreted as proof that low-income rural households are benefiting more from the solar transition. Solar adoption can also represent a response to inadequate grid infrastructure or unreliable electricity access. Finding 4 = Solar energy

² Source: Pakistan Bureau of Statistics, HIES 2024–25.

has become particularly important in rural household electricity provision, suggesting that distributed solar may serve both as a development technology and as a substitute or complement where conventional electricity infrastructure is weaker.

Table 8: Household Lighting Sources by Urban/Rural Location, 2024–25³

Source	Urban	Rural	Pakistan
Electricity	87%	71%	78%
Electricity + solar	9%	12%	11%
Solar	2%	11%	7%
Other	1%	6%	4%

Solar Energy and Energy Security: Energy security receives partial support from the national electricity data. Pakistan's total installed capacity reached 46,605 MW by July–March FY2025. Hydropower, nuclear, and renewable sources collectively accounted for 44.3% of installed capacity, while thermal sources accounted for 55.7%. More importantly, when actual electricity generation rather than installed capacity is considered, hydropower, nuclear and renewable sources collectively contributed 53.7% of electricity generation during July–March FY2025.

Table 9: Electricity Generation by Source, July–March FY2025⁴

Source	Generation (GWh)	Share
Hydel	27,413	30.41%
Thermal	41,734	46.30%
Nuclear	17,175	19.05%
Renewable	3,823	4.24%
Total	90,145	100%

The data indicate that Pakistan's electricity generation remains heavily dependent on thermal sources. Therefore, the solar transition should be described as strengthening energy diversification, rather than as having eliminated fossil-fuel dependence. This distinction is essential for a rigorous academic argument. Finding 5 = Solar expansion is contributing to diversification of Pakistan's electricity system, but the evidence does not support the conclusion that solar has yet displaced thermal generation at a system-wide level. Electricity Consumption and the Emergence of Off-Grid Solar: An additional finding concerns declining grid electricity consumption. During July–March FY2025, national electricity consumption declined from 83,109 GWh to 80,111 GWh, a reduction of approximately 3.6%. The Economic Survey attributes this partly to conservation measures, high electricity tariffs, off-grid solar solutions, and subdued industrial activity. This finding has two possible interpretations. One interpretation is positive: households and businesses are increasingly using solar energy to meet electricity requirements, thereby reducing dependence on the grid. The second interpretation is more complex: declining

³ Source: PBS HIES 2024–25.

⁴ Source: Pakistan Economic Survey 2024–25 / NEPRA.

grid consumption can also reflect high electricity prices and reduced electricity affordability. Consequently, lower grid consumption cannot by itself be interpreted as evidence of improved energy welfare. Finding 6 = The decline in grid electricity consumption is consistent with increasing solar substitution, but it also highlights the affordability pressures facing Pakistani electricity consumers.

Solar Energy and Energy Poverty: The evidence concerning energy poverty is more nuanced. HIES 2024–25 reports that 96% of Pakistani households have electricity or solar as a lighting source. Therefore, conventional electricity-access measures would suggest that Pakistan has made substantial progress. However, electricity access alone does not adequately capture energy poverty. A household may have electricity but still experience unaffordable electricity bills, unreliable supply, insufficient electricity for cooling/heating, dependence on backup systems, or inability to purchase solar technology. This means that the study's multidimensional Energy Poverty Index is preferable to a simple electricity-access indicator. The evidence currently available supports the following interpretation: Pakistan has moved closer to universal basic electricity/solar lighting access, but affordability and reliability remain important dimensions of energy poverty. The Economic Survey itself identifies energy affordability, sustainability, and security as continuing challenges in FY2025.

Is Solar Energy Inclusive? The findings provide a mixed picture. On the one hand, rural households show substantial use of solar technology. Solar-only lighting is reported by 11% of rural households compared with 2% of urban households. On the other hand, ownership of a complete household solar system generally requires an initial capital investment. Consequently, two distinct forms of solar adoption need to be distinguished: Type 1) Solar as an inclusion technology. Solar can provide electricity to households where grid infrastructure is weak or unreliable. Type 2) Solar as a private investment. Higher-income households may install relatively large systems to reduce electricity bills and protect themselves from tariff increases. These two forms of solar adoption have different implications for inclusive development. Thus, the central finding is not that solar energy is inherently inclusive or exclusive. Rather: Finding 7 = The inclusiveness of Pakistan's solar transition depends substantially on who can afford, access, and benefit from solar technology. This is precisely why household-level HIES analysis is important.

Energy Transition and Income Distribution: The HIES 2024–25 provides nationally representative information on household income and expenditure and contains data for 32,814 households across Pakistan. The survey also provides household information by expenditure quintiles, allowing solar adoption and energy expenditure to be analysed across socioeconomic groups. If solar ownership increases systematically with household income, the transition could produce a two-tier energy system, in which wealthier households increasingly become energy self-sufficient, and poorer households remain dependent on the conventional grid. Conversely, if rural and lower-income households demonstrate substantial solar adoption, solar could function as an important mechanism of energy inclusion. The HIES microdata regression should be used to determine which of these patterns is statistically supported. It would therefore be inappropriate to insert a numerical coefficient or significance level into the paper until the microdata are actually estimated.

Policy and Institutional Findings: The policy analysis shows that Pakistan's solar transition is supported by a substantial institutional framework. The Pakistan Economic Survey identifies the

Alternative & Renewable Energy Policy 2019, National Electricity Policy 2021, and the Indicative Generation Capacity Expansion Plan as important elements of the country's electricity-sector transformation. The government's Fast-Track Solar Initiatives also explicitly identify substitution of expensive imported fossil fuels with solar PV as a policy objective. The policy framework therefore connects solar energy to energy security, foreign-exchange pressures, electricity affordability, import substitution, environmental sustainability, and electricity access. However, the rapid expansion of household solar also creates a policy challenge. If financially capable consumers increasingly generate their own electricity, the conventional grid may lose some high-value consumers while retaining network costs and poorer consumers. This creates an important distributional question: Who finances the electricity network when affluent consumers increasingly become self-generating consumers? This question should become one of the paper's central discussion points. Table 10 demonstrates the structural change in Pakistan's electricity system without requiring any estimation.

Table 10: Pakistan's Installed Electricity Capacity by Source⁵

Energy source	FY2024 MW	FY2024 share (%)	July–March FY2025 MW	July–March FY2025 share (%)
Hydel	10,635	23.18	11,368	24.39
Thermal	28,766	62.69	25,937	55.65
Nuclear	3,620	7.89	3,620	7.77
Renewable	2,867	6.25	5,680	12.18
Total	45,888	100.00	46,605	100.00

Table 11: Electricity Generation by Source, July–March FY2025⁶

Energy source	Generation (GWh)	Share (%)
Hydel	27,413	30.41
Thermal	41,734	46.30
Nuclear	17,175	19.05
Renewable	3,823	4.24
Total	90,145	100.00

Table 11 demonstrates an important distinction between installed capacity and actual electricity generation. Renewable sources represented 12.18% of installed capacity but only 4.24% of electricity generation during the period. Thermal generation remained the largest contributor at 46.30%. This suggests that Pakistan's transition is progressing in terms of capacity deployment faster than in terms of actual electricity generation.

⁵ Note. Renewable capacity in July–March FY2025 includes 2,813 MW from net metering. Source: Pakistan Economic Survey 2024–25, based on NEPRA and NTDC data.

⁶ Source: Pakistan Economic Survey 2024–25 / NEPRA.

Table 12: Household Lighting Sources in Pakistan: 2018–19 and 2024–25⁷

Lighting source	2018–19 (%)	2024–25 (%)	Change (percentage points)
Electricity	91	78	–13
Electricity + solar	—	11	+11
Solar panels	4	7	+3
Other	4	4	0
Total electricity/solar access	95	96	+1

The most important finding is not a dramatic increase in basic electricity access—it increased from 95% to 96%. Instead, the composition of electricity access has changed. Exclusive electricity use declined from 91% to 78%, while hybrid electricity-and-solar use reached 11% and solar-only lighting reached 7%. This supports the argument that Pakistan's energy transition is increasingly characterised by diversification of household electricity sources (Table 12).

Table 13: Urban–Rural Distribution of Household Lighting Sources, 2024–25⁸

Lighting source	Urban (%)	Rural (%)	Pakistan (%)	Rural–urban difference
Electricity	87	71	78	–16
Electricity + solar	9	12	11	+3
Solar panels	2	11	7	+9
Other	1	6	4	+5
Total	100	100	100	—

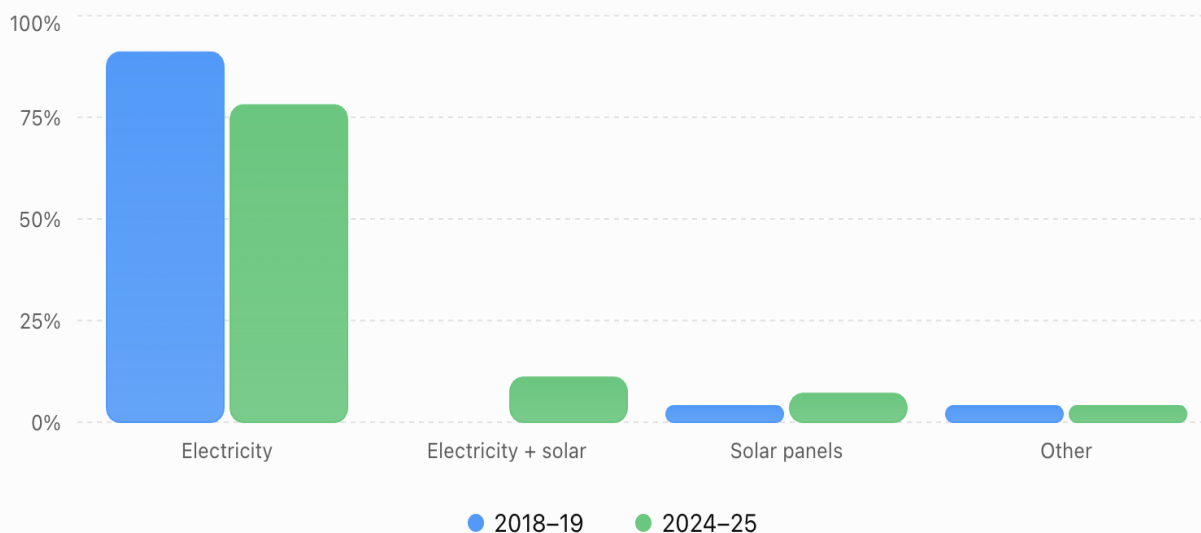
Table 13 indicates that solar-only lighting is reported by 11% of rural households compared with only 2% of urban households. At the same time, conventional electricity-only lighting is substantially more common in urban areas. The result indicates that solar is playing an important role in rural energy provision. However, this should not automatically be interpreted as evidence that rural households are economically better off. Solar may also be compensating for weaker grid infrastructure or unreliable electricity.

⁷ Source: Pakistan Bureau of Statistics, HIES/PSLM 2024–25.

⁸ Source: PBS HIES/PSLM 2024–25.

Household lighting sources in Pakistan

Comparison of household lighting sources between 2018–19 and 2024–25.



Source: Pakistan Bureau of Statistics, HIES/PSLM 2024–25.

Figure 2: Household Lighting Sources in Pakistan⁹

Table 14: Pakistan's Electricity Consumption by Sector, July–March FY2025¹⁰

Sector	Electricity consumption (GWh)	Share (%)
Household	39,728	49.6
Industrial	21,065	26.3
Agriculture	4,568	5.7
Commercial	6,889	8.6
Other sectors	7,861	9.8
Total	80,111	100.0

The household sector accounted for almost half of Pakistan's electricity consumption during July–March FY2025. This makes household solar adoption particularly relevant to the study's energy-poverty and inclusive-development dimensions (Table 14).

Table 15: Change in Electricity Consumption¹¹

Indicator	July–March FY2024	July–March FY2025	Change
Electricity consumption (GWh)	83,109	80,111	–2,998

⁹ The underlying PBS figures are reported in the HIES 2024–25 results.

¹⁰ **Source:** Pakistan Economic Survey 2024–25.

¹¹ **Source:** Pakistan Economic Survey 2024–25.

Indicator	July–March FY2024	July–March FY2025	Change
Percentage change	—	—	–3.6%

The Economic Survey identifies energy conservation, elevated tariffs, off-grid solar solutions, and subdued industrial activity among factors associated with the decline. This finding is important because declining grid consumption should not automatically be interpreted as improved energy welfare. It may reflect both substitution toward solar and affordability pressures (Table 15).

Table 16: Solar Transition and Energy-Security Indicators¹²

Indicator	FY2024	July–March FY2025	Direction of change
Total installed capacity (MW)	45,888	46,605	↑
Renewable capacity (MW)	2,867	5,680	↑↑
Renewable share of capacity (%)	6.25	12.18	↑↑
Thermal share of capacity (%)	62.69	55.65	↓
Net-metering capacity (MW)	—	2,813	↑
Total electricity generation (GWh)	127,523	90,145*	—
Renewable share of generation (%)	4.81	4.24*	—
Thermal share of generation (%)	45.74	46.30*	—

Table 16 produces a very useful finding for the paper: Pakistan's renewable transition is considerably more visible in installed capacity than in electricity generation. That is a stronger and more academically defensible conclusion than simply stating that "solar is transforming Pakistan."

Discussion:

Solar Transition as an Energy-Security Strategy: The evidence indicates that solar energy is becoming an important component of Pakistan's energy-security strategy. The increase in renewable capacity and the presence of 2,813 MW of net-metering capacity indicate that solar is no longer a marginal component of the electricity system. The significance of solar extends beyond environmental benefits. Pakistan remains exposed to international fossil-fuel prices and foreign-exchange constraints. Solar generation does not eliminate these vulnerabilities because panels, batteries, and related equipment may themselves depend on imported components, but generation from solar can reduce exposure to recurring fuel requirements. Therefore, solar energy can be conceptualised as contributing to strategic energy diversification.

Solar Transition as an Energy-Poverty Intervention: The findings also suggest that solar has the potential to address energy poverty. The increase in solar and hybrid household systems indicates that households are not simply waiting for grid-based infrastructure to improve. They are increasingly adopting decentralised alternatives. The rural data are particularly important. The 11% share of rural households reporting solar-only lighting indicates that solar is becoming

¹² FY2025 figures cover July–March rather than the full fiscal year, so they should not be interpreted as directly equivalent annual totals.

Source: Pakistan Economic Survey 2024–25.

relevant beyond affluent urban neighbourhoods. However, the affordability of initial installation remains an important barrier. Consequently, government policy should distinguish between access to solar technology and capacity to invest in solar technology.

The Politics of Inclusive Development: The phrase “politics of inclusive development” in the title should not be treated simply as a reference to party politics. It refers to the institutional choices that determine who receives subsidies, who can access financing, who can install solar, who can participate in net metering, who bears grid-maintenance costs, who benefits from reduced electricity bills, and who remains dependent on conventional electricity. The solar transition therefore involves a distributional dimension. The central policy question is not simply: How much solar capacity can Pakistan install? It is: Who gains from Pakistan's solar transition, and under what institutional arrangements? This provides the paper with a stronger social-science contribution.

Energy Justice Dimension: The findings can also be interpreted through an energy-justice framework. Three dimensions are particularly relevant: Distributive justice: Who receives the economic benefits of solar? Procedural justice: Who participates in decisions concerning tariffs, net metering, and renewable-energy policy? Recognition justice: Are the needs of rural, low-income, and underserved communities adequately recognised in energy policy? The HIES findings demonstrate why these questions matter. Rural households have higher solar-only usage, but this does not necessarily establish that they have equal access to financing, technology, or electricity services.

Table 17: Summary of Empirical Findings

Research question	Evidence	Preliminary finding
Has solar expanded?	Renewable capacity reached 5,680 MW	Yes
Is distributed solar important?	2,813 MW net metering	Yes
Has household electricity access improved?	95% → 96%	Marginally
Has the composition of electricity access changed?	Electricity-only 91% → 78%, hybrid/solar increased	Substantially
Is solar relevant in rural areas?	Solar-only: 11% rural vs 2% urban	Yes
Has the electricity mix diversified?	Renewable share of capacity: 6.25% → 12.18%	Yes
Has thermal generation disappeared?	Thermal = 46.3% of generation	No
Has grid consumption declined?	83,109 → 80,111 GWh	Yes
Is lower grid consumption necessarily lower energy poverty?	Tariffs + off-grid solar + conservation identified as factors	Cannot be concluded from aggregate data
Is solar inclusive across income groups?	Requires HIES microdata analysis	To be empirically tested

Conclusion:

Pakistan's solar energy transition represents more than a shift toward renewable electricity generation. The evidence demonstrates an emerging transformation in the relationship between

households, electricity markets, and the state. Renewable installed capacity increased to 5,680 MW by July–March FY2025, while 2,813 MW was associated with net metering. At the household level, solar and hybrid electricity systems have become increasingly visible, with 11% of rural households reporting combined electricity-and-solar use and another 11% relying on solar panels as their lighting source. Nevertheless, the transition remains incomplete. Thermal generation continues to account for 46.3% of electricity generation, while energy affordability remains an acknowledged national challenge. The evidence therefore supports a more nuanced interpretation of Pakistan's solar transition. Solar energy is simultaneously an energy-security mechanism, a household coping strategy, a potential energy-poverty intervention, and a new site of socioeconomic distribution and policy contestation. The key question for Pakistan's next phase of energy policy is consequently not simply how rapidly solar capacity can expand. The more consequential question is whether the benefits of that expansion can be made accessible to households and communities that currently face the greatest energy and financial constraints.

Policy Implications:

- i. **Targeted solar financing:** Government financing programmes should prioritise households that cannot meet the upfront cost of solar systems.
- ii. **Rural solarisation:** The strong rural uptake documented by HIES suggests that decentralised solar can form an important component of rural energy policy.
- iii. **Protect low-income grid consumers:** Changes to net-metering and electricity tariffs should consider the distributional consequences for households that cannot afford solar installations.
- iv. **Develop inclusive financing:** Banks and public financial institutions could provide concessional financing, leasing and pay-as-you-go mechanisms for smaller household solar systems.
- v. **Integrate batteries into energy policy:** Solar panels alone do not guarantee electricity availability after sunset. Battery storage should therefore be considered within future energy-security planning.
- vi. **Strengthen consumer protection:** The rapid growth of the solar installation market makes technical standards, installer certification, warranties, and consumer-protection mechanisms increasingly important.
- vii. **Develop a multidimensional energy-poverty measure:** Pakistan's energy policy should move beyond the binary indicator of whether a household has electricity. Energy affordability, reliability, quality, and ability to meet essential energy needs should also be incorporated.

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