Shouting from the Rooftops: Quantifying Pakistan's Solar Revolution

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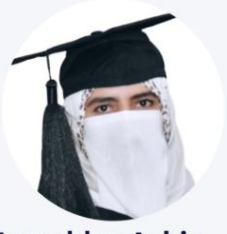

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Executive Summary

Overview	Against total solar panel imports of 50 GW, Pakistan's on-ground installations have reached 33 GW, reflecting strong nationwide uptake. The residential segment remains the primary driver of distributed solar growth, accounting for the majority of installed capacity. The actual installed capacity of rooftop and off-grid systems far exceeds officially reported figures, highlighting the rapid and largely undocumented pace of solar adoption.
Sectoral Adoption Trends	The survey reveals that the residential sector leads national solar adoption, accounting for almost 50% (16.6 GW) of total installed capacity, including net-metered systems. The industrial sector follows with 7.9 GW, while agriculture and commercial sectors contribute 5.04 GW and 3.7 GW, respectively. This distribution reflects a grassroots energy transition across all consumer categories—driven primarily by unreliable and expensive grid electricity, which continues to push consumers toward self-generation.
Changing Consumption Patterns	Nearly 77% of solar adopters continue to use the grid as a backup source while relying primarily on solar for self-consumption. This trend indicates that distributed solar is not merely replacing existing demand but is also creating new, unaccounted demand that remains absent from official power planning models. The analysis further shows that while solarization is a nationwide phenomenon, macroeconomic factors influencing reduced grid consumption vary across income groups. In the industrial sector, a significant portion of lower- and upper-middle-income industries reported a decline in grid electricity use, reflecting cost-saving behavior and self-sufficiency efforts.
Residential Sector Insights	Within the residential segment, socio-economic status strongly influences both adoption rates and system sizes. Higher-income households demonstrate greater adoption levels and larger system capacities, whereas low-income groups show limited adoption due to affordability constraints and lack of access to financing options.
Commercial Sector Insights	In the commercial sector, medium-scale businesses represent the highest rate of solar adoption, balancing investment capacity with operational energy needs. A positive correlation is observed between income level and solar PV adoption, suggesting that affordability remains a key determinant of uptake across business sizes.
Industrial Sector Insights	In the industrial sector, solar adoption rates scale with the size of operations. Larger industries tend to invest in higher-capacity systems, while smaller industries face challenges due to limited capital and financing access. The findings also indicate a shift in barriers as income levels rise—from financial constraints among lower-income industries to technical.
Agriculture Insights	Solar adoption in agriculture rises with farm size, indicating strongest uptake among medium-scale farms. Adoption is highest among low-income farmers (84.7%) and strong among upper-middle-income groups (71.4%), driven by unreliable grid supply and long-term cost savings. Most adopters (83.7%) report reduced electricity use, reflecting lower grid dependence, while 22.1% operate entirely off-grid. Overall, solar is emerging as a key driver of energy independence in Pakistan's agricultural sector.

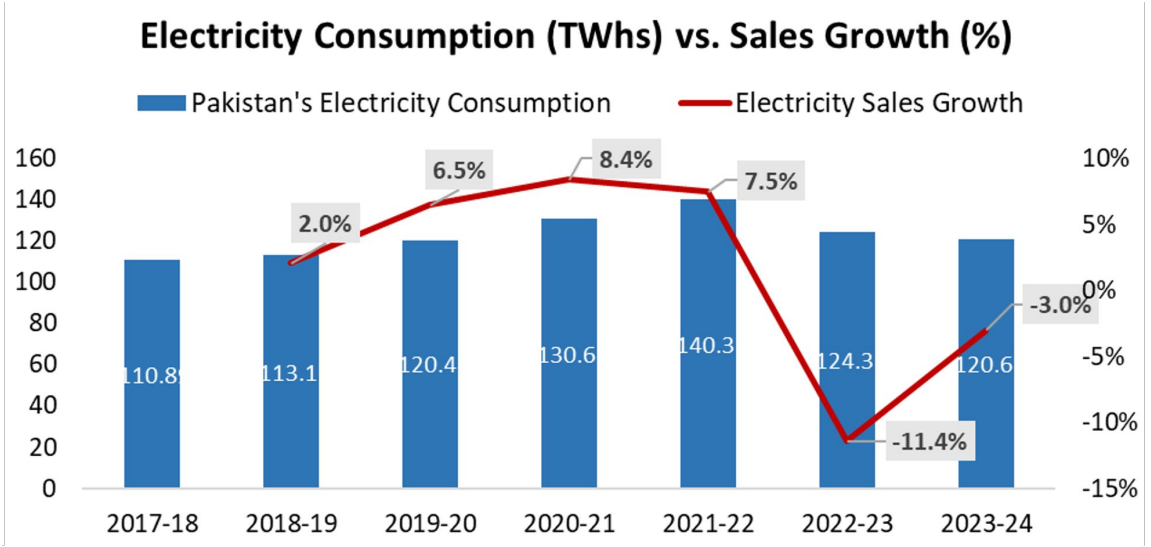
What is driving the decline in grid electricity sales — solar, reliability, or affordability, or a combination of all?

Pakistan's power sector remains burdened by rising generation costs, mounting circular debt, and inefficiencies in transmission and distribution.

Electricity prices have increased sharply across residential, industrial, and agricultural sectors, outpacing income growth and eroding affordability. **We see a 169% increase in domestic sector tariff since 2018.**

Persistent load-shedding with some of the areas facing more than 12 hours of load-shedding, voltage fluctuations, and unreliable grid supply have led the consumers to take charge of the situation.

In response, a growing number of households, businesses, and farms are turning to solar energy to secure reliable and cost-effective power.



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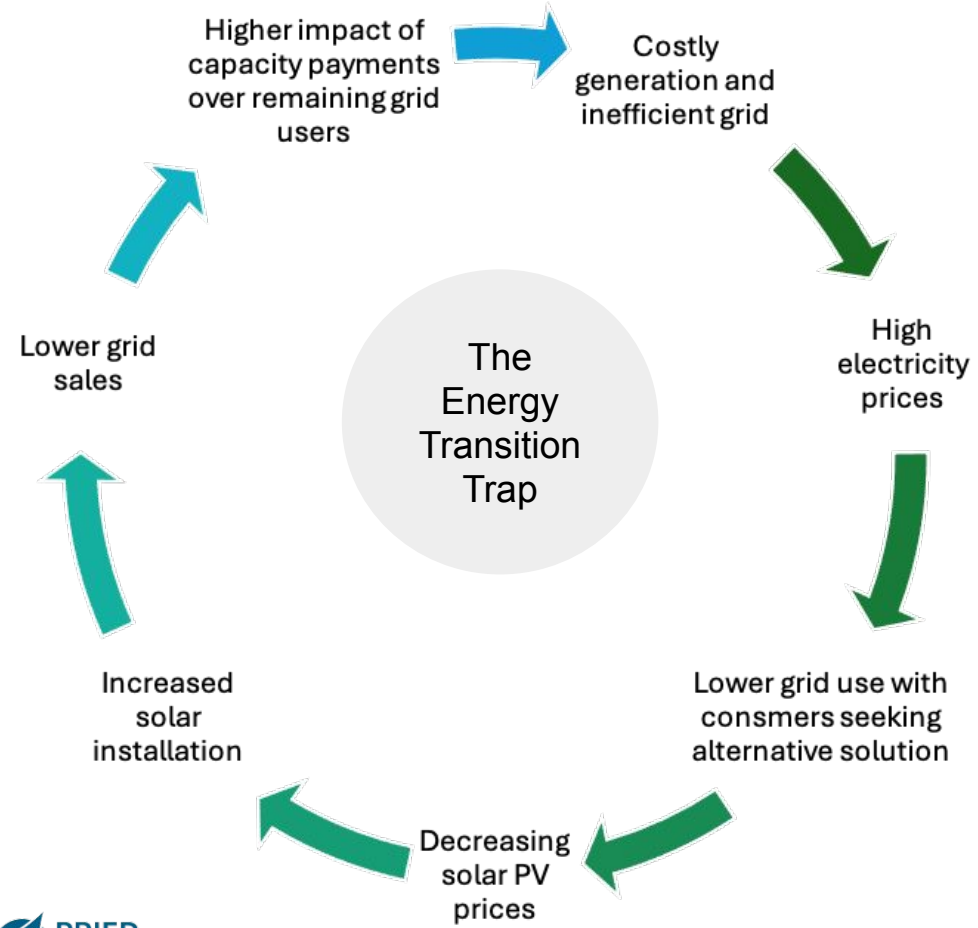
Source: State of Industry Report 2024 NEPRA

Yet, questions remain — is this shift driven solely by unreliable supply, or are broader macroeconomic pressures such as inflation, currency depreciation, and tariff escalation also shaping the solar boom?



We run into a vicious cycle where issues with the grid are driving exit from the grid or less reliance on the grid.

Those who are able are gradually shifting from the grid and decreasing their cost of energy.

Whereas grid electricity continues to be costly for consumers more reliant on the grid and are incapacitated to leave the grid or reduce their reliance on the grid.

Lower grid utilization further drives up electricity cost for end consumers.

Decreasing solar PV costs are providing a cheaper alternative to the energy consumers.

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The bulk of Pakistan's solar PV module imports, totaling over 50 GW over the past nine years, have originated from China

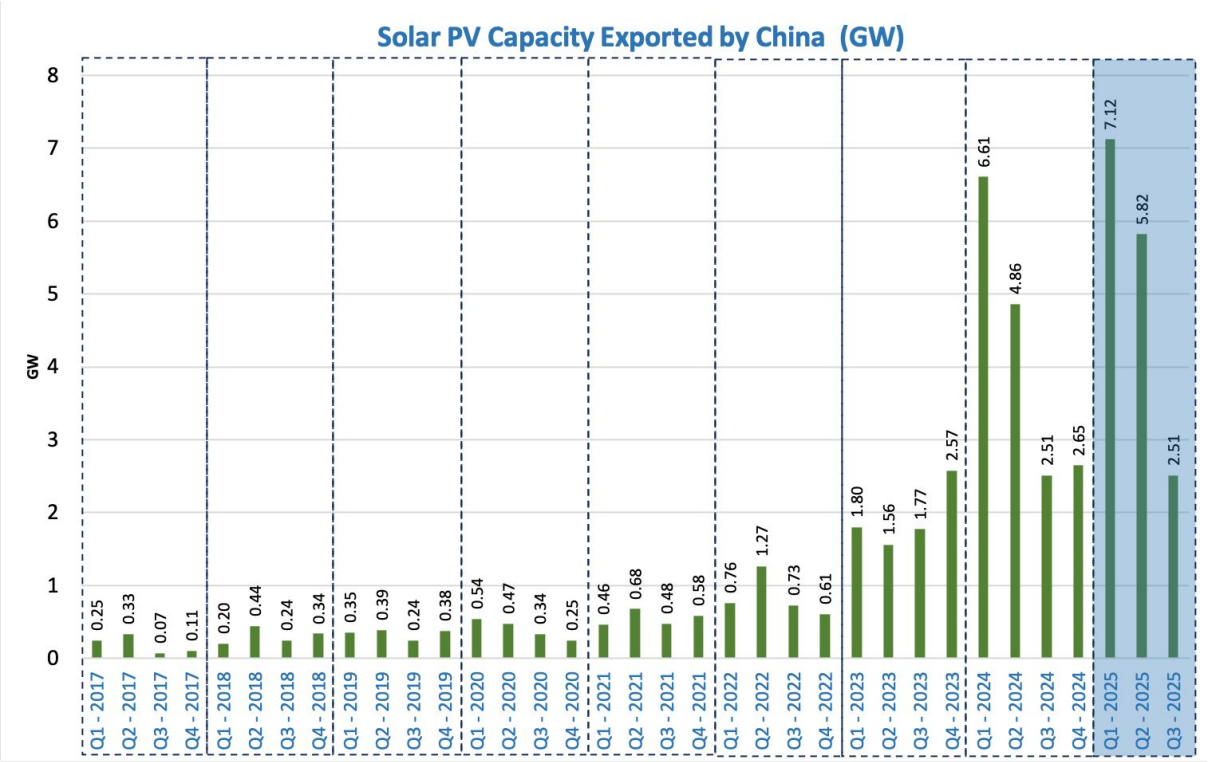
Over **50 GW** of solar panels have been imported into the country until August 2025, as per data available from Ember on China's Solar PV exports to Pakistan.

Near **17 GW** of solar PV were imported in 2024. Whereas, about **16 GW** of Solar PV panels have been imported only in the first three quarters of 2025.

7.7 GW were imported in 2023, more than double of solar PV capacity of **3.37 GW** imported in 2022.

This progression shows an exponential rise in the exports of solar PV from China to Pakistan.

Overall, Import value of Solar PV currently stands at **USD 5,226 Million** as per the data from Pakistan Trade Information Portal.



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Source: Ember China Solar PV Exports Data

While Solar PV imports are unprecedented, insufficient verifiable data exists on deployment of this imported quantum, which limits our ability to reflect on equitability of this solar transition.

Pakistan's solar imports capacity data is not centrally available.

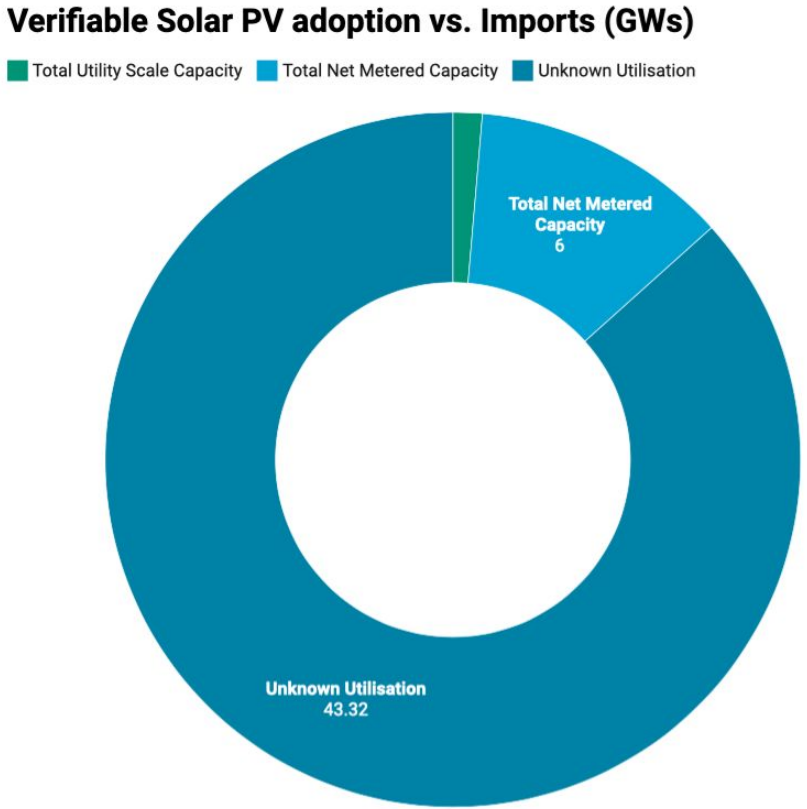
Available data on Trade Information Portal of Pakistan is not comprehensive and depicts mainly on value of solar PV imports.

The available numbers have also been scrutinized for their accuracy and transparency.[1,2]

Only verifiable data exists on 'net metering' and utility scale solar, which is available in the State of Industry Report issued by the power sector regulator NEPRA.

As per latest available net metering numbers and estimates, total net metered capacity across Pakistan stands at about 6 GW. Utility Scale solar stands at 680 MW.

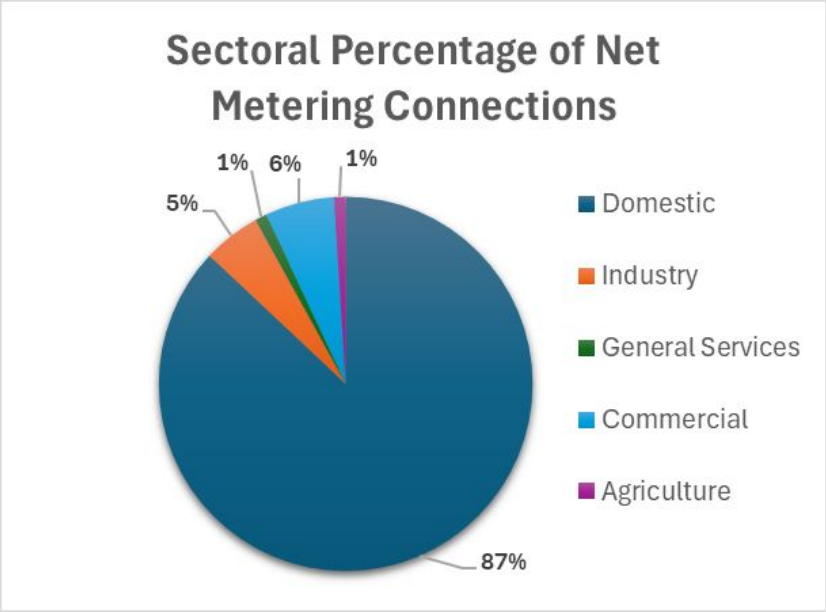
Data does not exist on a huge delta of about **43 GW.**

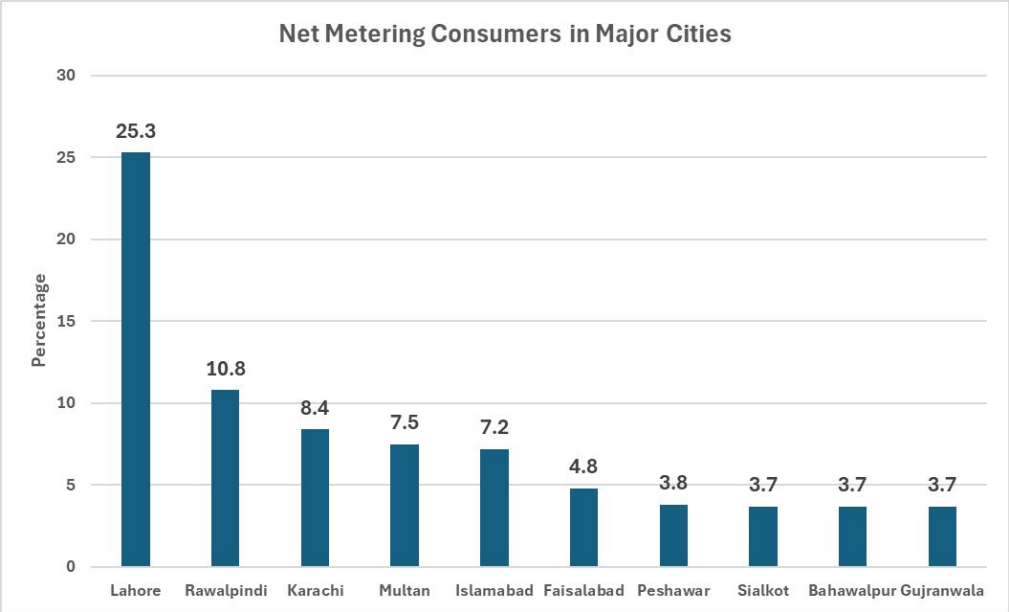


1 https://www.dawn.com/news/1891821#:~:text=On%20a%20larger%20scale%2C%20the,of%20money%20under%20false%20pretenses

2 https://www.energyupdate.com.pk/2025/08/01/fake-solar-panel-importers-fined-rs111-billion-for-massive-money-laundering-scam/#:~:text=KARACHI%2C%20Aug%201:%20In%20one,containers%20seized%20at%20Karachi%20Port)

Whereas, Net Metering quantum which has surpassed 6GW is predominantly concentrated in metropolitan centers and socioeconomically affluent areas.





Source: PPIB Consultation

Our hypothesis is that a huge delta of 43 GW cannot be possibly sitting in inventory, so there is a significant number of solar adopters which are either behind-the-meter (BTM) or are completely off-grid.

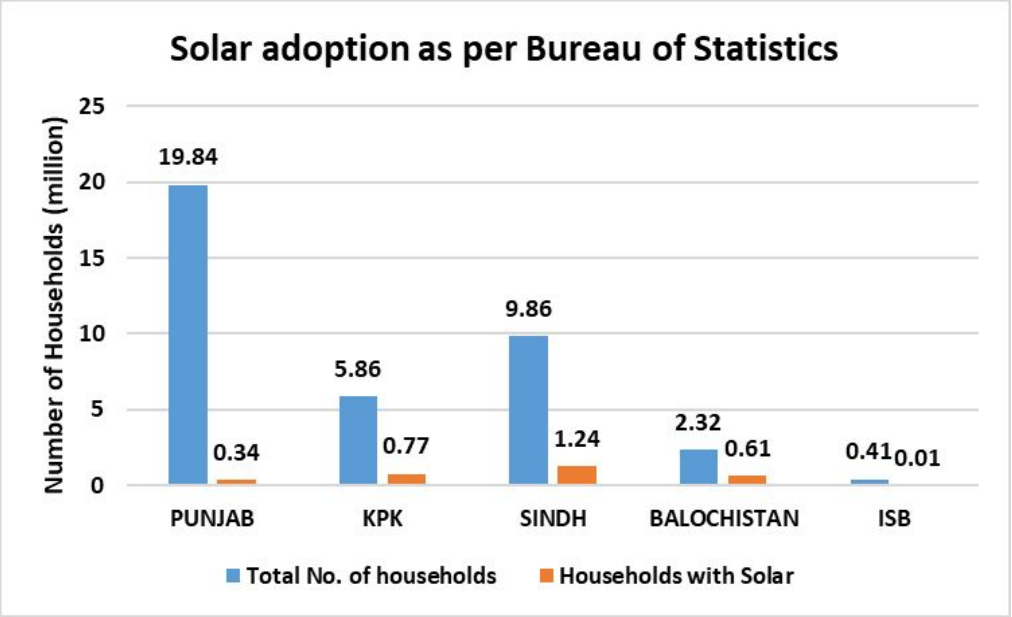
Reviewing census data from Bureau of Statistics, we witness that there are **more solar households reported than the number of net-metered households in NEPRA State of Industry Report.**

- Net-Metered Households: 134,531 (2024)
- Solar Households (PBS): 2,962,152

Adoption Ratio based on PBS Census 2023:
Higher in KPK (0.13) and Balochistan (0.2) vs. other provinces; Punjab (0.01), Sindh (0.12), ISL (0.02).

Net metering data solely cannot be relied upon to get the whole picture of solar adoption in the country, as its data clearly underreports the number of households which are using solar.

For instance, in our rural electrification study in Naushki district, Balochistan, field survey results showed that around 66% of rural households had installed solar systems to meet their basic energy needs.



Source: PBS Census 2023

Our study aims to understand, reconcile, and bridge the data gap on solar adoption while evaluating the equitability of solar revolution in Pakistan

Map on-ground solar adoption including undocumented *behind-the-meter* installations.

Assess the scale and spatial distribution of solar adoption across the *residential, commercial, industrial, and agricultural* sectors.

Analyze adoption trends and their impact on grid electricity demand and consumption patterns across different *income groups* — low-, middle-, and high-income households.

Identify barriers to solar adoption among non-users and determine how *income disparities* and affordability constraints shape the energy transition

Evaluate the influence of macroeconomic factors — such as fiscal instability, declining exports, and overall economic slowdown — on national grid electricity demand.

Examine the socio-economic implications of rising solar adoption within *provincial, urban, and rural* contexts.

The study further examines whether Pakistan's surge in solar imports truly reflects a *just energy transition*, or if deeper social, economic, and regional inequities must be addressed to make the shift genuinely inclusive.

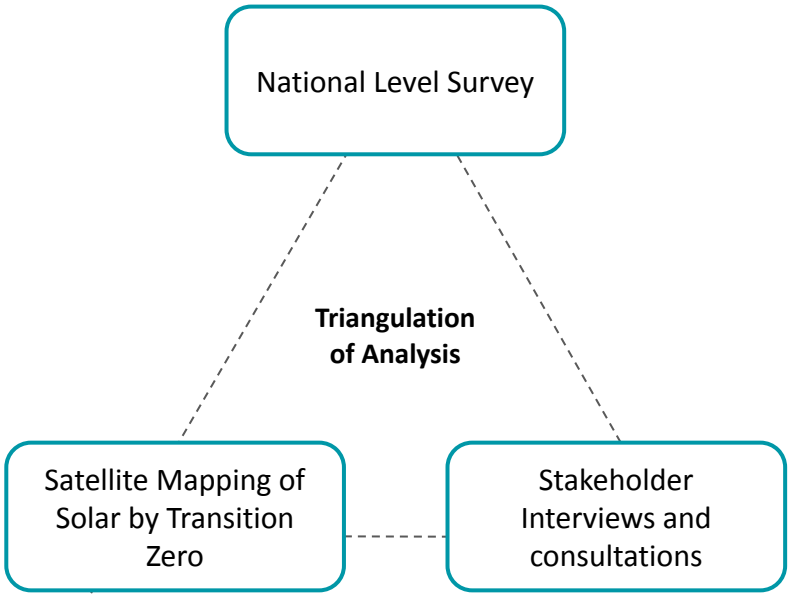
A mixed-methods approach has been followed to comprehensively carry out the study for solar adoption assessment in the country.

Secondary Data Analysis

- Reviewed national and provincial datasets (NEPRA, PPIB, PBS, NTDC, FBR).
- Analyzed solar import data, market trends, and policy frameworks.
- Identified inconsistencies and data gaps, especially for behind-the-meter systems.

Primary Data Collection and Analysis

- A nationally representative solar adoption survey was conducted to quantify real installation levels and usage trends.
- Focused on capturing behind-the-meter adoption across residential, commercial, industrial, and agricultural sectors.
- Also assessed changes in energy consumption patterns and user behavior.



Objective: To generate an empirical baseline that complements official statistics and supports evidence-based planning for Pakistan's distributed solar transition.

The national level survey is designed with robust coverage, statistical validity, and data credibility

1. Sample Design & Scale:

Total Respondents	5,320 (5,120 across provinces + 200 in Islamabad)
Sampling Technique	Stratified random sampling based on urban/rural division and provincial population shares (PBS Census 2023).
Allocation	50% fixed (640 per province) + 50% proportional to population share

2. Coverage:

Sectors	Residential, commercial, industrial, and agricultural.
Strata	Urban/rural, province, income groups, and consumer categories
Sectoral Distribution	Urban: Residential 50%, Industrial 25%, Commercial 25%. Rural: Residential 50%, Agricultural 30%, Commercial 15%, Industrial 5%.

3. Implementation & Quality Assurance:

Survey Tool	KOBO Toolbox; Pilot testing conducted for survey refinement
Real-time Monitoring	GPS tracking, time stamps, and geotag verification
Data Validation	Random back-checks, duplicate removal, outlier detection

4. Statistical Validity:

Design Objective	National Level Representation with ±5% margin of error
Weighting Strategy	Design, response, and post-stratification weights applied to ensure accuracy.
Deliverables	· National, provincial, and sectoral solar adoption profiles. · Comparative analysis of adopters vs. non-adopters. · Energy consumption profiles by sector and province.

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Bathinda
Kurukshetra
Uttarakhand
Kaithal
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Sri Ganganagar
Sirsa
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Gorakhpur
Deoria
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Gwalior
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Deoghar
West Bengal
Chittorgarh
Guna
Rewa
Singrauli
Palanpur
Udaipur
Mandsaur
Gangtok
Darjeeling
Siliguri

As per PRIED's analysis, over 33 GW of solar has been installed against the 50GW of imported solar

- Adoption of solar PV has reached **33.34 GW** surpassing country's peak demand on the grid which is about 28-30 GW during summers.
- The country's current grid's installed capacity is about 46 GW.
- The table on right shows solar adoption quantum across different provinces.
- The residential sector is leading in adoption followed by industrial sector, agriculture and commercial sectors.
- Solar adopters are relying predominantly on their installed PV systems (77% of surveyors), using the grid mainly to supplement (23%) their energy demand.
- Residential demand met by solar is highest in high end urban centers like Islamabad (78%) followed by KPK (60–65%) and Punjab (48%).
- Sindh and Balochistan lag behind with one-third of their energy demand met by solar on average.

Regions	Net Metering (GW)	Non Net Metered (GW)	Off-grid (GW)
Punjab	4.9	8.49	4.39
KPK	0.64	5.47	2
Sindh	0.03	3.53	1.44
Balochistan	0.02	0.93	0.48
ICT	0.44	0.57	0.01
Total	**6.03**	**19**	**8.31**

Residential	Commercial	Industrial	Agriculture	Total
16.66	**3.73**	**7.91**	**5.04**	**33.34**

Source: PRIED's on-ground survey 2025

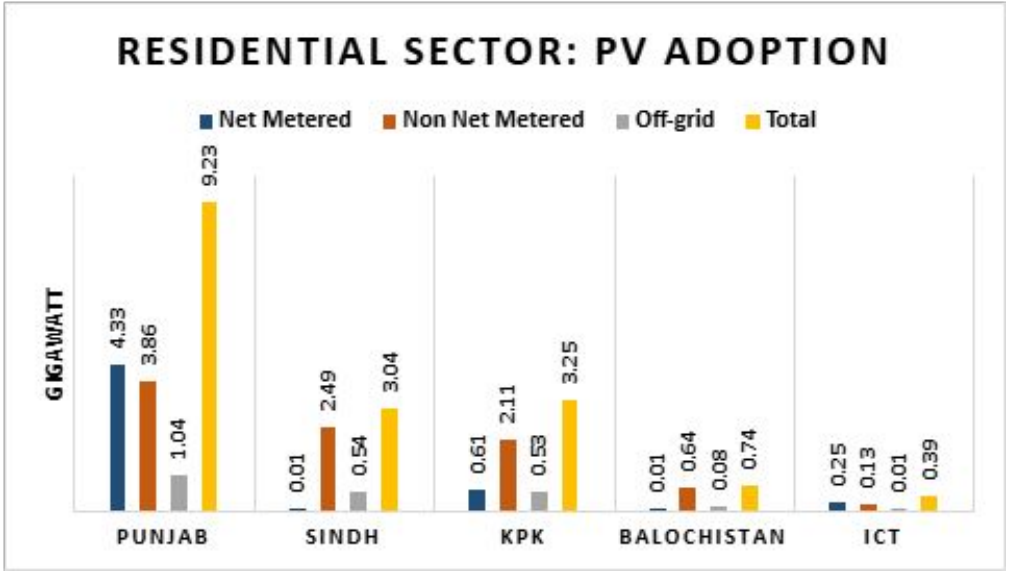
Residential Sector Analysis

Our analysis indicates 16.66 GW of Solar PV adoption in the Residential Sector — Leading Pakistan's Solar Transition

Residential solar installations across Pakistan totals **16.66 GW**, with net-metered (NM) systems accounting for **5.22 GW**, non-net-metered (NNM) for **9.24 GW**, and off-grid systems for **2.2 GW**.

Punjab leads with **9.23 GW** of residential capacity—over half of the national total—followed by Sindh 3.04 GW, KPK 3.25 GW, Balochistan 0.74 GW, and ICT (0.39 GW).

Punjab also dominates in both net metered and non net metered installations.



Net Metered	Non Net Metered	Off-grid	Total
5.22 GW	9.24 GW	2.20 GW	16.66 GW

Source: PRIED's on-ground survey 2025

The Residential Solar Rush: Implications for Non-Adopters and the National Grid

Load Reduction and Peak Shifting: The proliferation of residential rooftop PV systems has substantially reduced **daytime grid load**, particularly in Punjab. However, because most households lack adequate storage, **evening peak demand remains high**, requiring greater ramping flexibility from the grid. This mismatch between solar generation hours and residential peak usage patterns increases the need for **load management, demand response, and reserve generation capacity,** and in general a well developed ancillary services market.

Revenue Erosion and Cost Shifting: As more households self-generate through NNM or off-grid systems, their grid consumption—and therefore contribution to system fixed costs—declines. Since overall network costs remain constant, **these costs are redistributed to non-solar consumers**, intensifying the burden on low- and middle-income households still reliant on the grid. This **cross-subsidy distortion** undermines tariff equity and poses long-term financial risks for DISCOs.

Tariff-Driven Acceleration of Solarization: The sharp increase in residential tariffs,over **150% since 2021**,has made rooftop PV an economically rational investment. For many households, **solar adoption now serves as a cost-avoidance strategy**, rather than a sustainability initiative. This dynamic has decoupled grid tariffs from demand growth, leading to **reduced elasticity** and declining revenue predictability for utilities. NM policy therefore needs immediate revision.

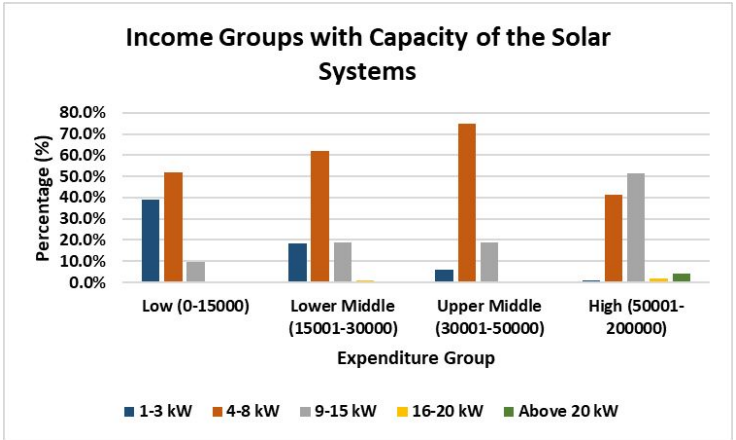
System-Wide Planning and Grid Modernization: The **domestic sector dominance in Pakistan's grid consumer base** means residential solarization directly affects system-wide demand forecasting, capacity planning, and revenue models. The national grid must increasingly operate as a **balancing and backup network**, absorbing variable injections from millions of prosumers.

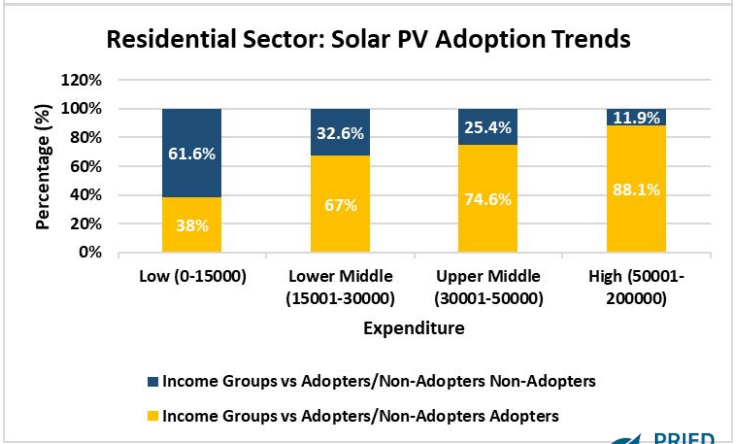
At lower socioeconomic levels, solar adoption is lower than at higher socioeconomic levels raising critical equity challenge

Low-income households (electricity expenditure up to **PKR 15,000**) predominantly install small-scale systems—39% in the **1–3 kW** range and 52% between **4–8 kW**—reflecting limited purchasing power and constrained financing options. In contrast, lower-middle and **u**pper-middle income groups increasingly favor mid-sized system**s** (over 60% and 75% in the **4–8 kW** range, respectively), while high-income households tend toward larger capacities (52% for **9–15 kW** and 6% exceeding **15 kW**).

Solar adoption rates rise correspondingly with income: **38%** among low-income, **67%** among lower-middle, **75%** among upper-middle**,** and **88%** among high-income households. This gradient underscores that **affordability and capital accessibility** remain the primary determinants of energy transition participation.

As wealthier households increasingly self-generate, **grid costs are redistributed to non-adopters**, who remain captive to the utility system. These consumers—mostly **low- and middle-income households**—face escalating electricity tariffs. For many **electricity bills now consume a significant share of disposable income**, constraining essential expenditures and deepening energy-related financial stress.





Source: PRIED's on-ground survey 2025

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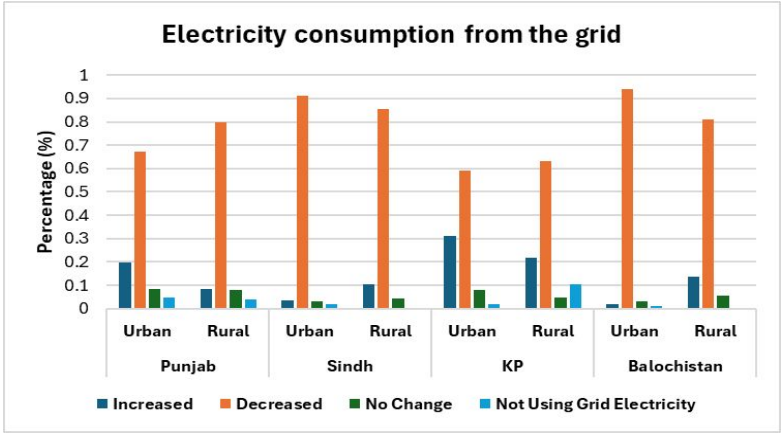
As prices and unreliability rise, consumers are self-selecting out of the grid

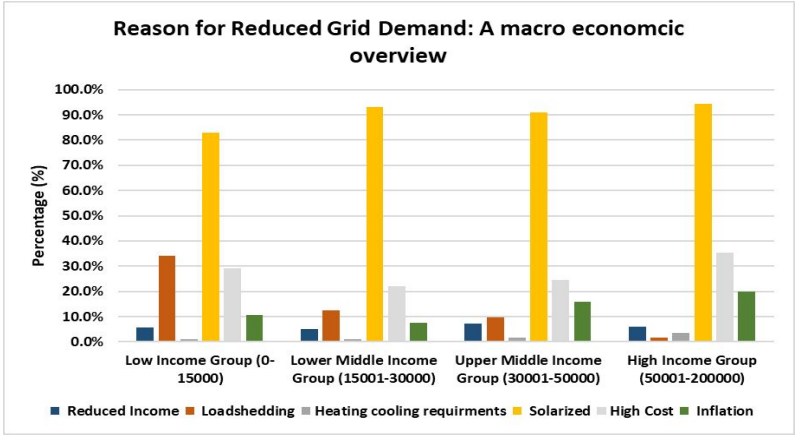
Across all income groups, solarization has become the dominant factor driving the reduction in residential grid electricity consumption in Pakistan. Survey findings indicate that **over 90% of middle- and high-income households** identified solar adoption as the principal reason for decreased grid reliance, while **83% of low-income users** also attributed their reduced consumption to self-generation.

This shift has been reinforced by persistent macroeconomic and energy-sector pressures. Between FY2021 and FY2024, average consumer electricity tariffs rose by more than 150% driven by rising capacity payments, rupee depreciation, and fuel price volatility. For many households, grid electricity has thus become financially unsustainable, making rooftop solar a cost-avoidance and survival strategy rather than merely a green investment.

At the same time, **unreliable grid supply and prolonged load-shedding**, particularly in high-loss feeders across Punjab and Sindh, have further eroded consumer confidence in the grid. Households increasingly perceive self-generation as a means to ensure **energy reliability and autonomy**, especially during prolonged summer outages.

While solarization remains the primary driver of reduced grid demand, other factors also play a role, particularly among low-income households. For these groups, the decline in grid consumption is a mix of necessity and affordability pressure, as high tariffs and unreliable service limit their ability to sustain previous consumption levels.





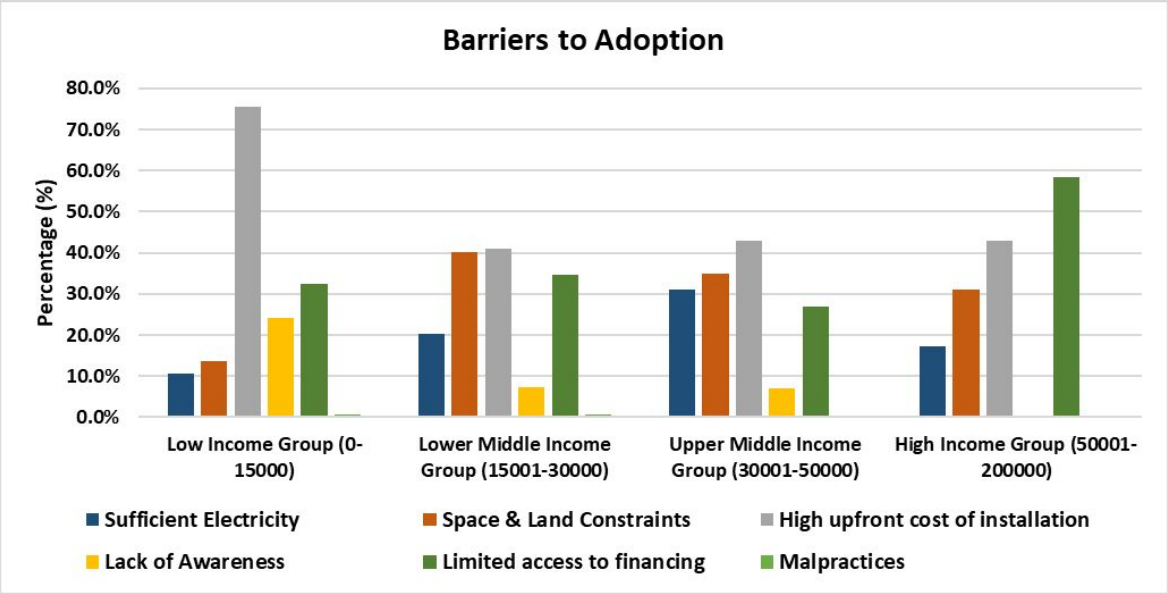
Source: PRIED's on-ground survey 2025

Barriers to Solar PV Adoption

Solar adoption barriers vary by income. Low-income households (electricity expenditure) up to PKR 15,000) face high upfront costs (75.4%), limited financing (32%), and lack of awareness (24%).

Lower-middle income groups cite space constraints (40%), high costs (41%), and limited financing (24%). Upper-middle income households also cite cost (42%) and space (34%), but less lack of awareness.

High-income segments surprisingly find limited financing (58.3%) the dominant issue, followed by upfront costs (43%) and space constraints (31%).



Source: PRIED's on-ground survey 2025

Affordability and financing are persistent barriers across all groups, while awareness gaps are more prevalent in lower-income households.

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Commercial Sector Analysis

Commercial Sector is still lagging in Solar adoption scale

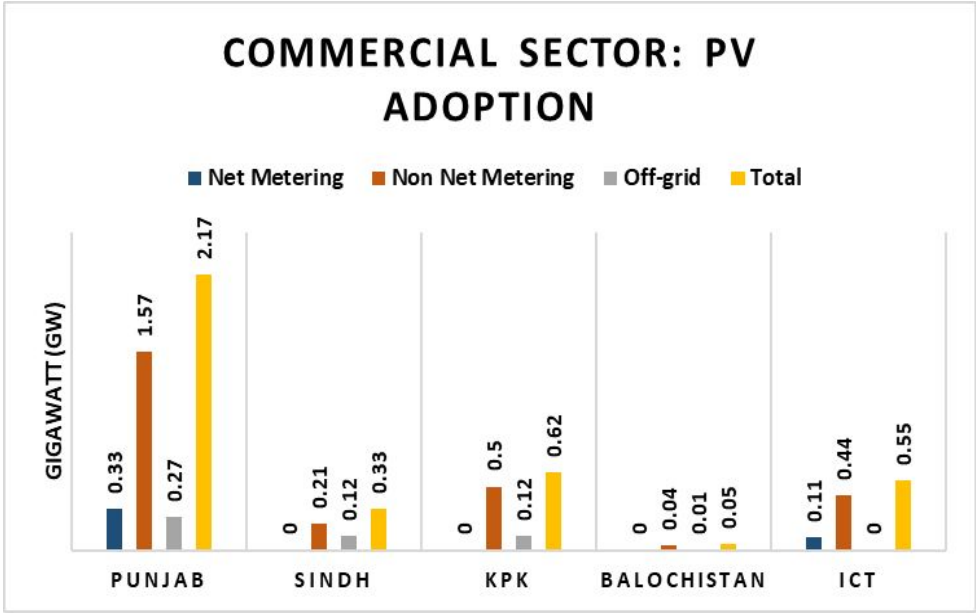
Punjab dominates the commercial solar landscape with **2.17 GW** of installed capacity, comprising **1.57 GW non-net-metered (NNM)**, **0.33 GW net-metered (NM)**, and **0.27 GW off-grid** systems.

Khyber Pakhtunkhwa (KP) ranks second, with **0.62 GW** in total — primarily **0.5 GW NNM** and **0.12 GW off-grid**.

Sindh follows with **0.33 GW**, including **0.21 GW NNM**, **0.12 GW NM**, and a negligible share of off-grid systems.

Islamabad Capital Territory (ICT) shows **0.55 GW** total capacity, driven mainly by **0.44 GW NNM** and **0.11 GW NM**, reflecting strong adoption among service-oriented and retail businesses.

Balochistan remains the smallest contributor, with **0.05 GW total**, dominated by **0.04 GW NNM** and minor off-grid installations



Net-Metered (GW)	Non-Net Metered (GW)	Off grid (GW)	Total (GW)
0.45	2.76	0.52	3.73

Source: PRIED's on-ground survey 2025

Technical Implications of Commercial Solar Expansion on Pakistan's National Grid

Changing Demand Patterns: The growing number of solar rooftops in Punjab and ICT reduces daytime electricity demand from the grid. This changes the normal shape of the load curve and can make power system operation less predictable.
(Source: IEEFA, 2024 — "Pakistan's Distributed Solar Surge and Grid Implications")

Voltage Rise and Reverse Power Flow: When many commercial solar systems feed electricity back into the grid, the power can flow in the opposite direction of normal demand. This can cause voltage rise (over-voltage) and imbalance between phases.
LUMS (2022) found that on Lahore's low-voltage network, high solar export caused voltage levels to exceed safe limits and increased energy losses.
(Source: LUMS Energy Institute, 2022)

Power Quality Issues: Some commercial solar inverters and equipment introduce harmonics—tiny fluctuations in current and voltage—that can reduce power quality. Studies in Lahore confirmed that heavy rooftop solar export can make the local grid more sensitive to these distortions.
(Source: MDPI, 2021 — Harmonic Analysis of Grid-Connected Solar PV Systems in Lahore)

Impact on Grid Equipment: When power starts flowing backward, on-load tap changers (OLTCs) and protection systems in transformers may not work as designed. This can lead to unwanted switching, equipment stress, or risk of islanding (where part of the grid stays powered independently). LUMS (2022) observed that such reverse flows on Lahore's commercial feeders required updates to voltage control settings and protection schemes. *(Source: LUMS Energy Institute, 2022).* Solar power from rooftops uses inverters instead of spinning turbines, so it doesn't add to the grid's rotational inertia. With less inertia, the grid becomes more sensitive to sudden changes in supply or demand, which can affect frequency stability. *(Source: IEA, 2023 — Integrating Distributed Solar PV into Electricity Grids)*

Network and Planning Needs : With more commercial solar systems, utilities must assess how much new solar each feeder can safely handle. They also need real-time monitoring and forecasting tools to manage variable solar output and maintain reliable power delivery. *(Source: World Bank, 2024 — Pakistan Electricity Distribution Sector Assessment)*

Commercial sector faces disparities in Solar Adoption

Medium and Small Scale Enterprises Lead in Solar Adoption: Medium Scale businesses (50–249 employees) show the highest adoption rate, followed closely by Small Scale businesses (10–19 & 20–49 employees).

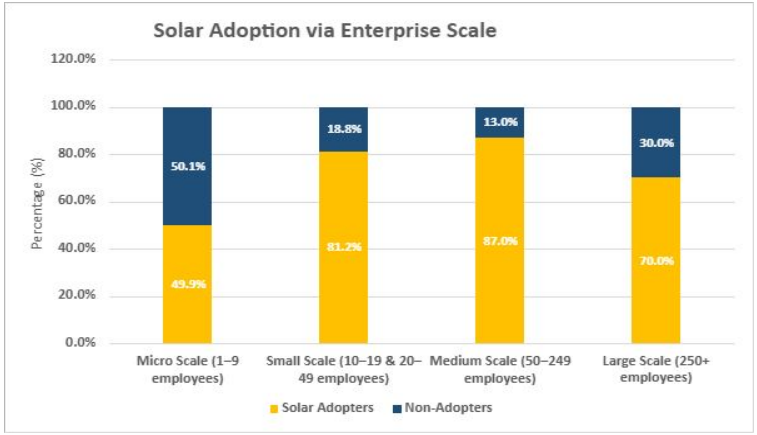
Micro Scale Enterprises Have the Lowest Adoption: Micro Scale businesses (1–9 employees) have the lowest adoption rate and the highest non-adoption rate.

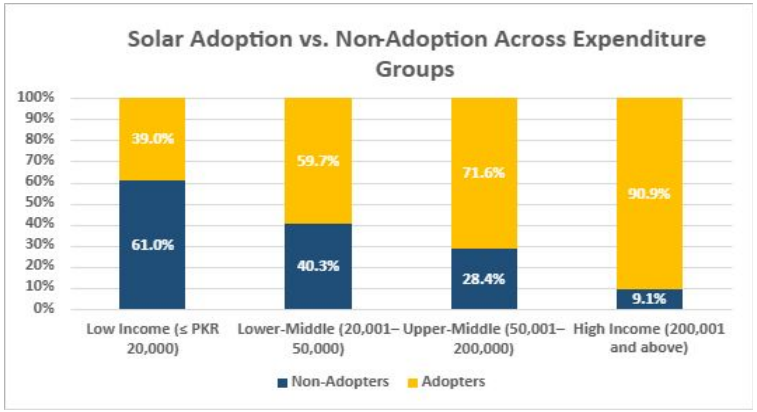
Large Scale Enterprises Have Moderate Adoption: Large Scale businesses (250+ employees) have a moderate adoption rate, higher than Micro Scale but lower than Small and Medium Scale enterprises.

Strong Correlation Between Income and Adoption: There is a clear positive correlation between income level and solar PV adoption. As income increases, the percentage of adopters significantly rises, and the percentage of non-adopters decreases.

Significant Disparity for Low-Income Groups: Low-income businesses have the lowest adoption rates and the highest non-adoption rates, indicating a substantial equity imbalance.

High-Income Groups Lead in Adoption: High-income businesses show exceptionally high solar PV adoption rates, suggesting that financial capacity is a major driver.





Source: PRIED's on-ground survey 2025

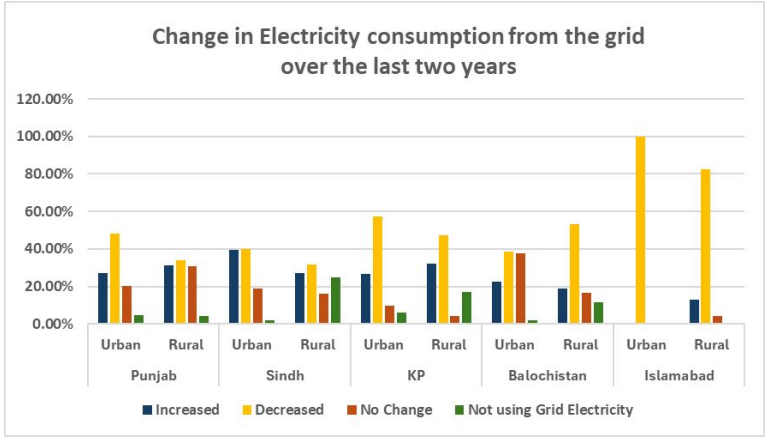
Solar is not the only player to blame for falling grid demand

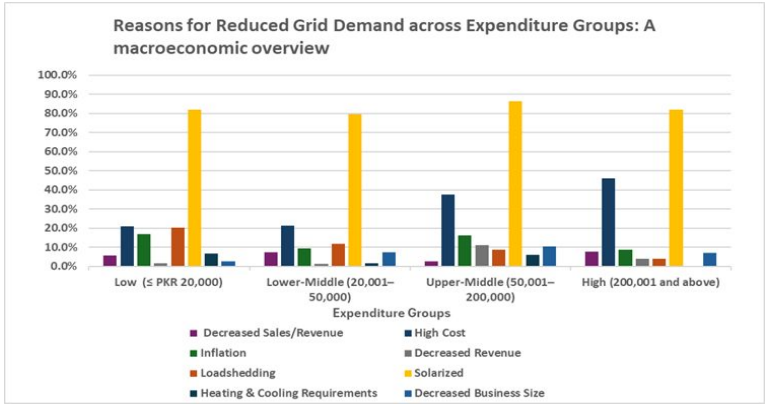
Solarization is a Universal Driver: "Solarized" is the most significant reason for decreased electricity demand across all income groups, consistently reported by over 79% of businesses in each category. This highlights the widespread adoption of solar PV as a primary factor in reducing conventional electricity consumption.

High Cost and Inflation Impact Middle Income Groups More: "High Cost" and "Inflation" are more frequently cited by upper-middle (37.3%) and high-income (45.8%) groups as reasons for decreased electricity demand, suggesting that these factors might influence their operational decisions more significantly than solar alone.

Load shedding and Decreased Revenue Affect Lower Income Groups More: "Load shedding" and "Decreased Revenue" are more prominent reasons for reduced demand among low and lower-middle income groups, indicating that these groups are more vulnerable to external economic pressures and unreliable electricity supply.

This analysis highlights that while solarization is a universal trend, other macroeconomic reasons for decreased electricity demand vary across income groups, reflecting different economic vulnerabilities and operational priorities.





Source: PRIED's on-ground survey 2025

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Industrial Sector Analysis

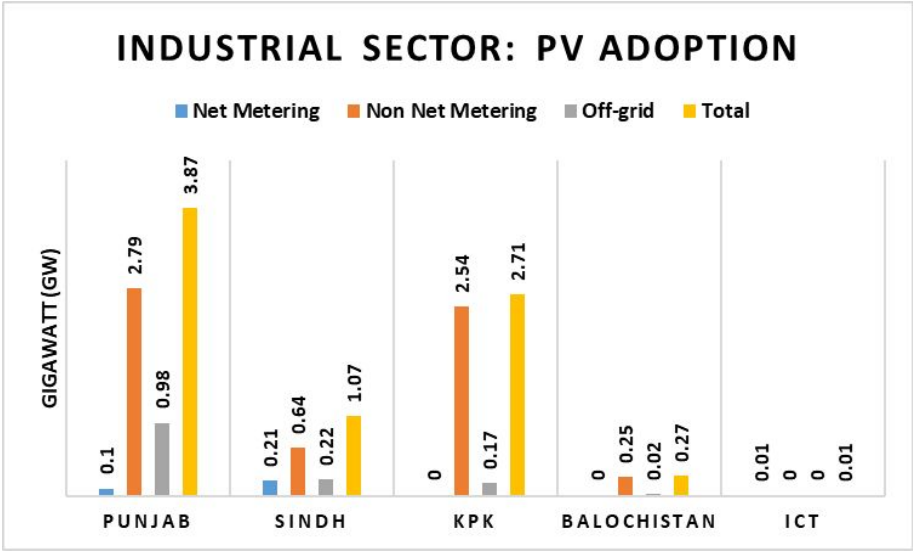
Trends in Industrial Solar PV Adoption shows more than 6GW is non-net metered out of total 8 GW

Punjab leads industrial solar adoption with a total of **3.87 GW** of installed capacity — comprising **2.79 GW of non-net metered (NNM)** systems.

Khyber Pakhtunkhwa (KP) follows as the second-largest industrial solar adopter, with **2.54 GW of NNM** capacity. While NM installations in KP's industrial sector are almost negligible, the province also has a notable **2.71 GW of total industrial PV adoption** capacity, indicating growing interest in self-sufficiency among industrial consumers.

Sindh ranks third, with a total of **1.07 GW** of industrial solar PV capacity

Overall, **industrial solar adoption now surpasses that of the commercial sector**, reflecting industries' strong motivation to reduce operating costs and reliance on the grid.



Net Metered	Non Net Metered	Off-grid (GW)	Total (GW)
0.30	6.22	1.39	7.91

Source: PRIED's on-ground survey 2025

Evolving Industrial Load Patterns under Rising Solar Penetration

While the number of grid electricity industrial consumers has continued to increase steadily, total electricity consumption has declined in recent years — **falling from 28,115 GWh in FY 2021–22 to 22,532 GWh in FY 2023–24**. This represents a nearly **20%** reduction in grid-based consumption, despite a growing number of connected industries.

This shift reflects a broader movement toward self-sufficiency through solar installations, particularly under non-net metered (NNM) and off-grid setups. As industries generate more of their own power, their dependence on grid electricity is shrinking, leading to a decline in productive grid demand. This has direct implications for DISCO revenues, system utilization, and long-term load planning.

Furthermore, with industries increasingly meeting their energy needs independently, their incentive to engage in the Competitive Trading Bilateral Contract Market (CTBCM) may weaken. If self-generation continues to expand, grid-based trading platforms could experience limited industrial participation, reducing their overall impact on market liberalization objectives.

At the system level, the growing penetration of daytime NNM generation reduces grid draw during solar hours, yet peak demand in the evening and nighttime remains high. This creates load management challenges and increases the risk of reverse power flows during low-demand hours, particularly in regions with concentrated solar adoption.

Looking ahead, the next phase of this transition is expected to be driven by battery storage integration. Our analysis shows that around **47% of current industrial solar adopters already have battery systems integrated with their PV setups**. This emerging trend could further reshape load profiles, reduce peak dependence, and transform grid interaction patterns in the coming years.

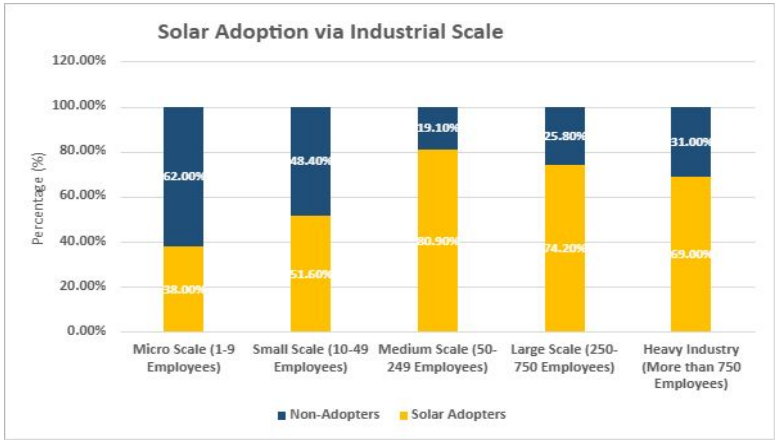
In Industries, a positive correlation exists between industrial scale and solar adoption

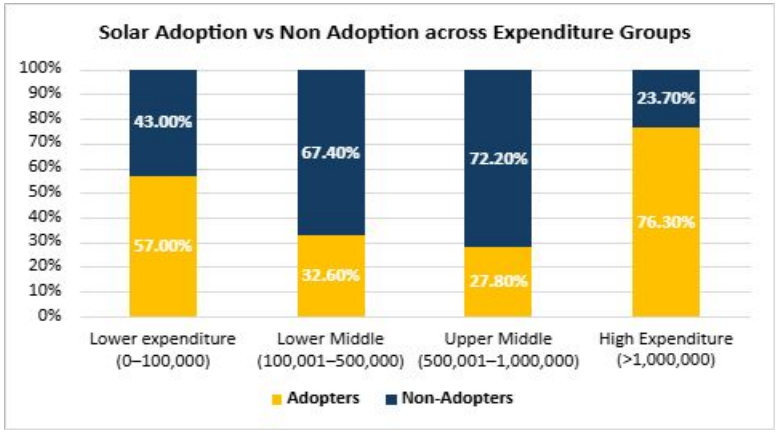
The data indicates a positive relationship between industrial scale and solar adoption, underscoring that access to renewable technologies is uneven across firm sizes. Adoption rates rise sharply from 38% among micro-scale industries to **80.9%** among medium-scale industries, suggesting that as enterprises expand, this enables greater investment in solar systems. Similarly, large-scale **(74.2%)** and heavy industries (69%) show strong adoption.

From an equity standpoint, this pattern highlights that smaller and lower-capacity industries face greater challenges in adopting solar

When segmented by monthly earnings, adoption is highest among high-revenue industries **(energy expend.>PKR 1 million) at 76.3%**, while lower-revenue industries **(expend≤PKR 100,000)** also show a relatively strong **57%** adoption rate, likely driven by the need to offset high grid tariffs and frequent supply interruptions. In contrast, adoption drops among lower-middle (**32.6%)** and upper-middle (**27.8%)** earning groups

Overall, the pattern forms a U-shaped relationship between financial scale and solar adoption, where both low-earning industries adopt solar out of necessity and high-earning industries adopt it as an optimization strategy.





Source: PRIED's on-ground survey 2025

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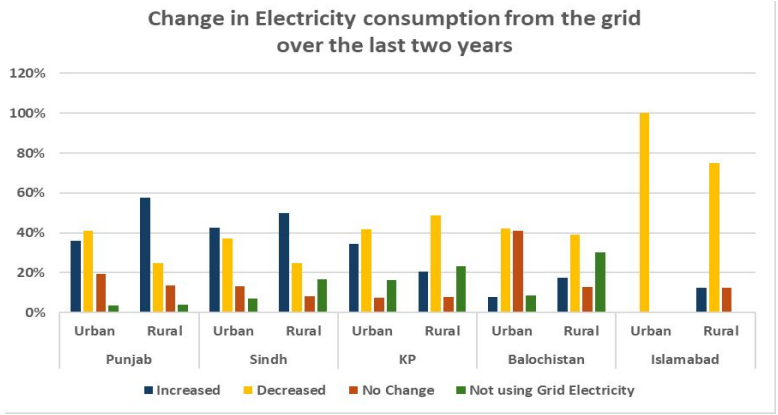
Declining trend in industrial grid electricity demand

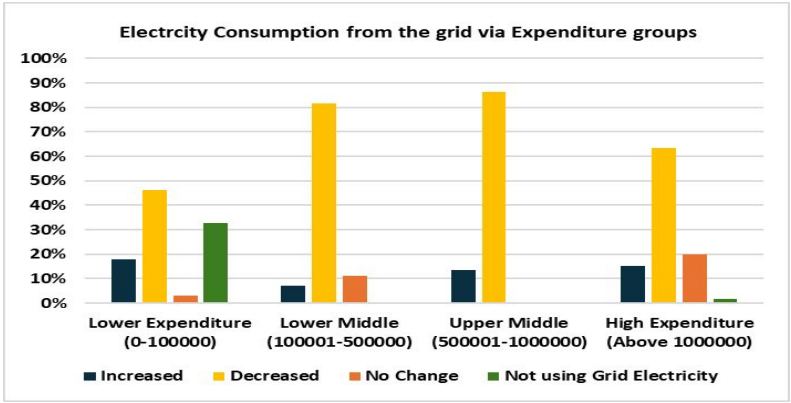
Grid electricity consumption trends vary by earning group. Lower-middle and upper-middle earning industries show significant decreases (81.5% and 86% respectively), indicating a strong shift to self-generation, especially solar.

Lower-earning industries also reduced grid dependence (46%) or are entirely off-grid (33%), favoring off-grid or hybrid systems.

High-earning industries (electricity expenditure > PKR 1,000,000) have a mixed pattern: 63% declined, 15% increased, and 20% remained unchanged, suggesting diversified energy portfolios integrating solar and grid supply.

Overall, **grid reliance is declining across all tiers,** most notably in middle-tier industries, driven by **high grid tariffs and increased solar adoption.**





Source: PRIED's on-ground survey 2025

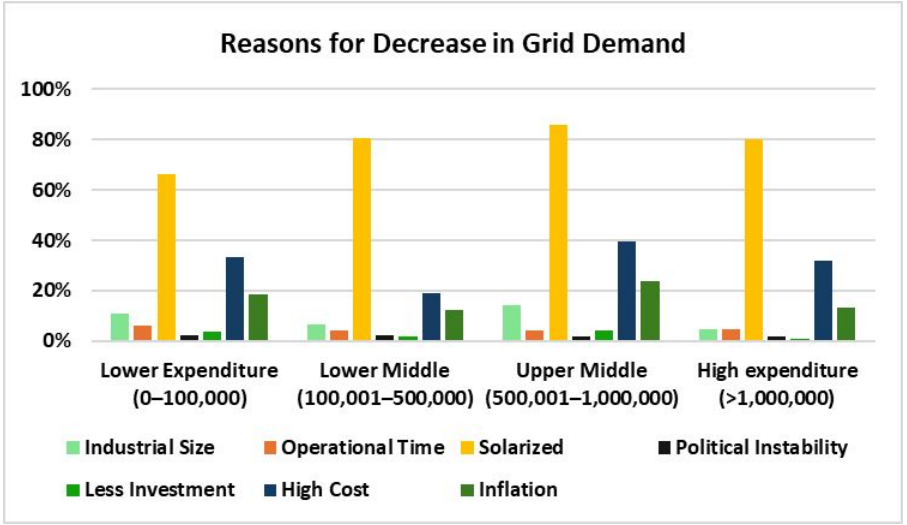
Solar is the universal indicator in the decreased demand but not the only one!

Lower-earning industries (electricity expenditure PKR 0–100,000) reported a **66.1%** reduction in grid electricity use due to solarization. High costs (**33.5%**) and inflation (**18.3%**) were also major contributing factors, while **11%** attributed reduced demand to smaller industrial size and **6%** to shorter operational hours.

Lower-middle earners (electricity expenditure PKR 100,001–500,000) showed the highest solar-driven decline, with **80.4%** citing solarization as the main cause. The impact of inflation (**12.2%**) and high costs (**18.9%**) was also notable, suggesting that smaller to mid-scale enterprises are increasingly shifting toward self-generation to offset economic pressures.

Upper-middle earners (electricity expenditure PKR 500,001 – 1,000,000) reflected the **strongest solar adoption effect at 85.8%**, followed by **high costs (39.5%)** and **inflation (23.8%)** as key drivers of lower grid consumption. About **14.2%** attributed demand reduction to smaller industrial size, showing that both structural and financial factors play a role in declining grid dependence.

High-earning industries (electricity expenditure>1,000,000 PKR) also reported strong solarization at **79.9%**, while **31.8%** pointed to high electricity costs and **13.5%** to inflation as contributing factors. A smaller share (**4.6%**) noted reduced operational hours and industrial scale effects

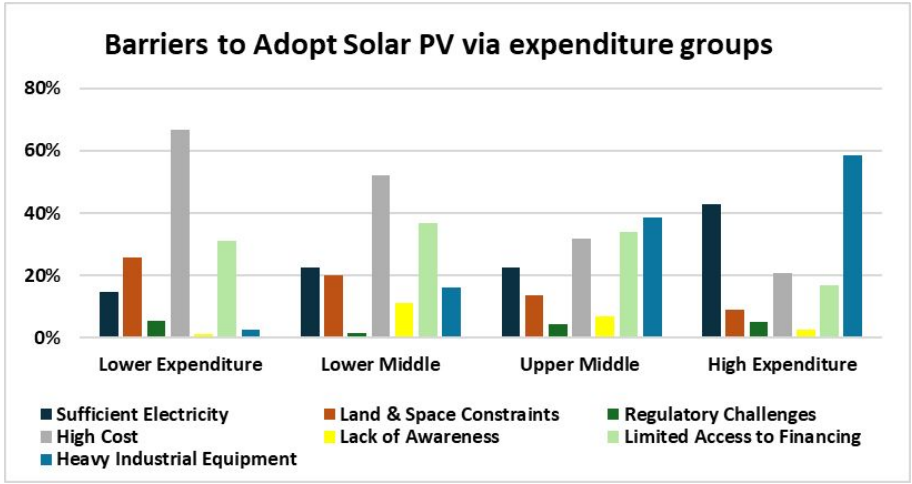


Source: PRIED's on-ground survey 2025

Barriers to Adoption of Solar PV in the industrial Sector

Among lower-income industries (electricity expend. 0–100,000 PKR), the high cost of installation (66.9%) and limited access to financing (31.1%) are the most dominant barriers, underscoring financial constraints as the primary deterrent.
Lower-middle-income industries also cite high costs (52%) and financing limitations (36.8%), while some report land and space constraints (20%) and lack of awareness (11.2%).

For upper-middle-income industries, financial concerns decline in prominence (31.8%), and barriers shift toward heavy industrial equipment compatibility (38.6%), reflecting more technical integration challenges. In contrast, high-income industries primarily identify sufficient electricity supply (42.9%) and equipment compatibility (58.4%) as limiting factors, suggesting that their adoption hesitation stems from technical and operational considerations rather than financial barriers.



Source: PRIED's on-ground survey 2025

Overall, the findings indicate a transition from financial to technical barriers as industrial income levels rise—lower-income industries struggle with affordability and financing, while high-income industries face integration and system compatibility challenges

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Agriculture Sector Analysis

Regional Distribution and Transition Trends in Agricultural Solar Adoption

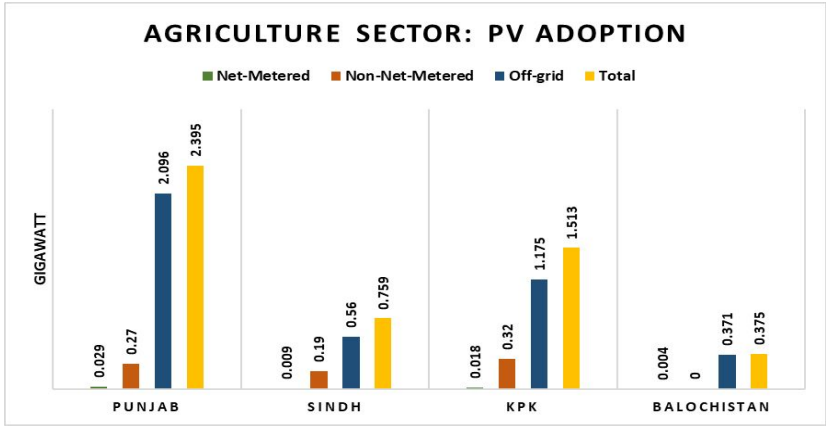
Punjab leads by a wide margin with a total of **2.38** GW installed agricultural solar capacity. This includes 2.09 GW off-Grid, **0.27 GW** non-net-metered (NNM), and a marginal net-metered share.

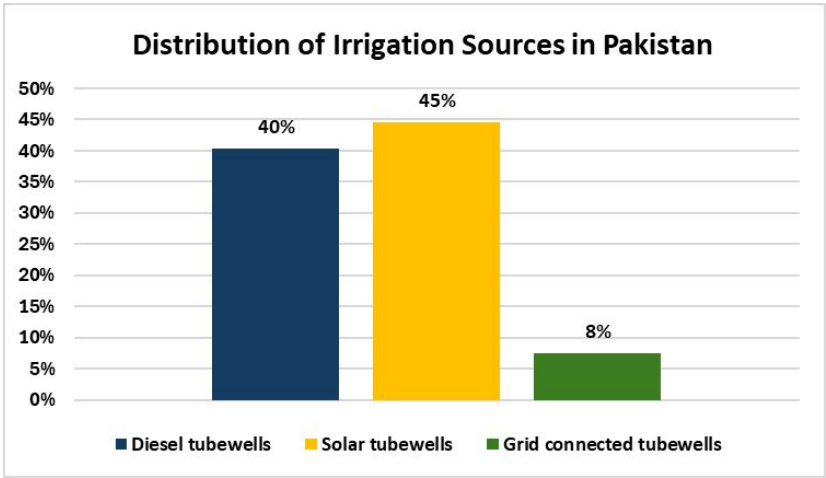
Khyber Pakhtunkhwa (KP) follows with **1.51** GW total, comprising **1.17** GW off-grid, **0.32** GW NNM, and **0.018** GW NM systems.

Sindh reports **0.76** GW total, consisting of **0.19** GW NNM, **0.09** GW NM, and **0.56** GW off-grid, indicating a mix of both connected and stand-alone solutions

Balochistan accounts for **0.38** GW total, with **0.37** GW off-grid with marginal NM and NNM capacities demonstrating reliance on localized, decentralized PV systems due to limited grid access.

Solar tubewells remain dominant nationally but Diesel tubewells remain the dominant irrigation source in Punjab, accounting for nearly **59%** of systems. However, there has been a substantial shift toward solar-powered irrigation in recent years. According to a Government of Punjab report (2021), around **80%** of the province's tubewells were diesel-based at that time, indicating a notable decline since then.



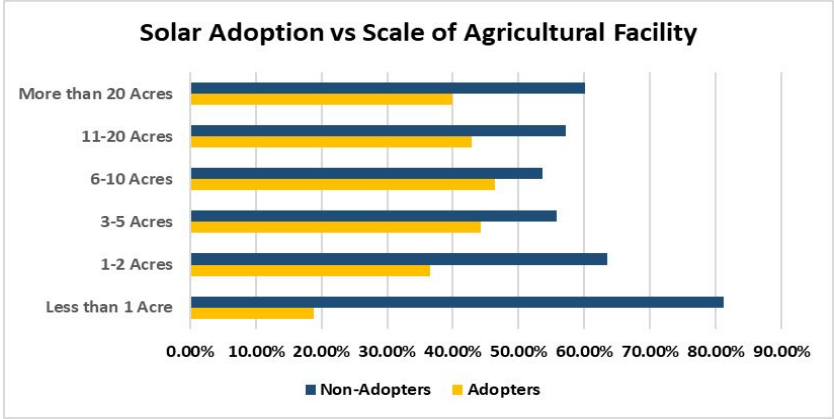


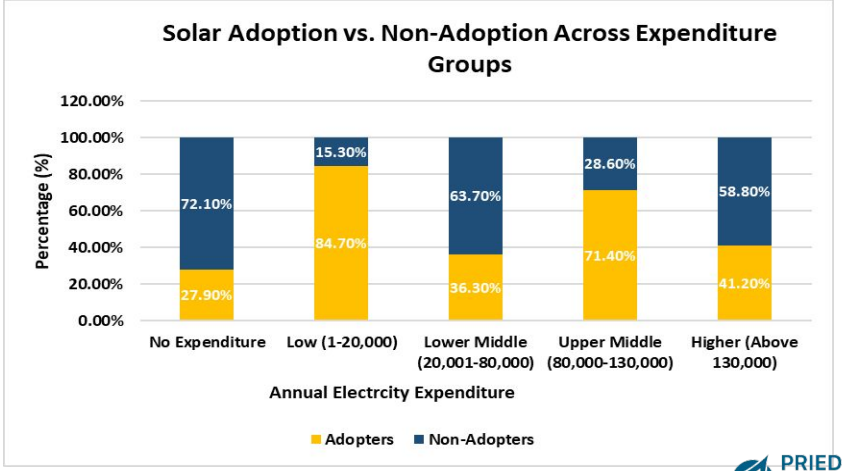
Source: PRIED's on-ground survey 2025

Adoption Rates rises as the scale of Agricultural facility Increases

The data illustrates a clear relationship between farm size and the likelihood of adopting solar technology. Adoption rates rise steadily as the scale of the agricultural facility increases—from just 18.8% among farms smaller than one acre to 46.4% among those spanning 6–10 acres. However, beyond this threshold, adoption slightly tapers off, with 42.8% adoption among 11–20 acre farms and 39.9% among those exceeding 20 acres. This trend suggests that medium-scale farms are the most active in adopting solar systems, likely due to their higher energy needs and greater capacity to invest compared to smaller farms, while very large farms may rely on alternative energy arrangements or have different operational priorities.

The data reveals notable variation in solar adoption across income groups. Adoption is highest among the lower expenditure group (1–20,000 PKR) at 84.7%, indicating that even low-income households are turning to solar—possibly due to unreliable grid supply and the long-term cost benefits of self-generation. The upper-middle-income group (80,000–130,000 PKR) also shows a strong adoption rate of 71.4%, reflecting both affordability and a preference for stable, clean energy sources.



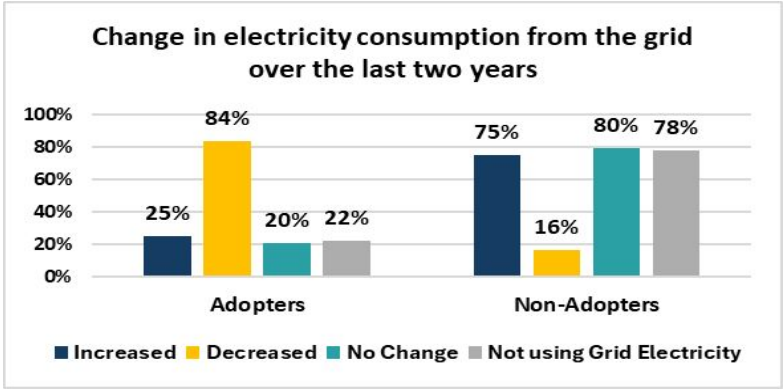


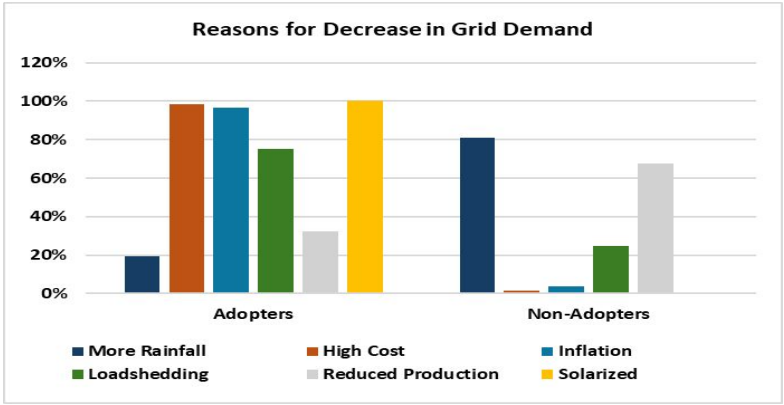
Source: PRIED's on-ground survey 2025

Solar PV significantly reduces energy poverty in the lower-income agriculture sector fostering energy independence and a true people-led ‘just energy-transition’

The data highlights distinct patterns in electricity consumption between solar adopters and non-adopters in agricultural facilities. A significant 83.7% of adopters reported a decrease in electricity consumption, reflecting the impact of solar installations in offsetting grid dependency and reducing energy costs. Conversely, only 24.7% of adopters noted an increase, which could be attributed to the expansion of operations or greater mechanization made possible by affordable solar power.

Among non-adopters, the majority reported either no change (79.6%) or continued reliance on grid electricity (77.9%), indicating limited efficiency improvements or energy diversification. Meanwhile, a smaller proportion of adopters (22.1%) are not using grid electricity, underscoring the role of solar as a standalone or hybrid energy source in off-grid agricultural setups. Overall, the findings suggest that solar adoption leads to substantial reductions in grid-based electricity consumption and enhances energy independence for agricultural users.





Source: PRIED’s on-ground survey 2025

Policy Area	Key Actions & Implications
🌞 **Distributed Solar Tracker**	Establish a regular mechanism to track and report distributed solar capacity across all sectors for accurate national data and planning.
⚙️ **Integrate Distributed Solar to Prevent Overcapacity**	Incorporate behind-the-meter and off-grid solar data into generation planning and demand forecasts to prevent overcapacity and optimize new additions.
🔌 **Optimize Grid Investments**	Reassess grid expansion plans considering falling grid demand; prioritize modernization, smart grids, and system efficiency.
🔋 **Promote Storage Integration**	Introduce incentives for pairing distributed solar with battery storage to enhance reliability and reduce peak-hour grid stress.
🔄 **Cross-Sector Coordination (All-Energy-Inclusive Framework)**	Strengthen coordination between gas, transport, and power sectors to anticipate demand shifts from solar electrification of heating and industry.
⚡ **Leverage Distributed Solar for Electrification**	Utilize distributed solar to support electrification of heating, cooking, and industrial processes—reducing reliance on gas and imports.
📊 **Reform Net-Metering Framework**	Update net-metering to reflect real system costs via time-of-use pricing, export caps, or dynamic netting to maintain fiscal sustainability.

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The combined efforts of the people mentioned above helped us ensure the accuracy, consistency and representativeness of the data collected from across the provinces, contributing massively to the strength and credibility of this study.

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