SOLARIZATION TRENDS IN INDUSTRY

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Alternate Development Services (ADS) extends its heartfelt gratitude to the solar companies, solar associations, and their representatives who participated in this study and generously shared their invaluable insight, information, and feedback. Their cooperation and contributions have been instrumental in advancing our understanding of energy consumption, renewable energy transition plans, challenges, and policy recommendations within the industry. Their commitment to sustainability and environmental stewardship is greatly appreciated and will undoubtedly pave the way for a greener, cleaner, and more sustainable future.

The ADS team is deeply indebted to the lead researcher and contributor, Abdul Haseeb Tariq, whose expertise and hard work were instrumental in shaping this study. We also extend our heartfelt gratitude to Amjad Mehdi, who contributed to methodology, draft writing, also sincere gratitude to Asad Khan for his invaluable supervision and policy advice. Special recognition goes to the enumerators, Muhammad Farhaan, Wahab Mughal, Abdul Jabbar, Muhammad Aleem, and Amir Roger, who demonstrated exceptional professionalism and dedication throughout the study. Their tireless efforts in conducting fieldwork, collecting data, and ensuring comprehensive coverage of relevant information as per the project's requirements were pivotal to its success. Their perseverance and commitment to excellence reflect the core values that underpin this initiative.

We also wish to acknowledge the collective efforts of all stakeholders and solar companies' representatives who supported us through their understanding, expertise, time, and resources. Their collaboration has laid a solid foundation for meaningful interventions and actionable strategies that help ADS to understand the current critical energy and sustainability challenges.

This study stands as a testament to what can be achieved through shared vision and collaborative action. We hope that the findings and recommendations serve as a catalyst for transformative change and inspire continued efforts toward achieving sustainable development goals.

Amjad Nazeer
CEO – Alternate Development Services.
Islamabad
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Nomenclature

AEDB	Alternative energy development board
CO2	Carbon dioxide
GW	Gega watt
KW	Kilo watt
KP	Khyber Pakhtunkhwa
LCOE	Levelized cost of energy
MW	Mega watt
O&M	Operational and maintenance
PV	Photovoltaic
PPIB	Private power and Infrastructure board
PLI	Production-linked incentive
ROI	Return on Investment
SMEs	Small and medium enterprises

Chapter 1

Introduction

1.1. Background

Global demand for sustainable and clean energy is increasing sharply as countries strive to reduce carbon emissions and combat climate change. Investment in renewable energy is surging. In 2025 alone, clean technologies like renewables, storage, nuclear, and grid infrastructure received funding around $2.2 trillion, which is twice the amount spent on coal, gas, and oil[1]. Major economies are driving the transition, as solar and wind dominated 92.5 % of new electricity capacity installed worldwide in 2024[2]. Meanwhile, fossil fuel-based energy production remains a large source of CO_2 and other greenhouse gas emissions, contributing to climate change and air pollution. This makes it clear that alternative and renewable technologies such as solar power are essential to meet clean energy goals.

In Pakistan, the energy mix as of FY 2024–25 was dominated by fossil fuels accounting for 55.6 % of installed capacity (≈ 25,937 MW) and generating 45.7 % of total electricity, while hydro and nuclear contributed 24.4 % and 7.8 %, respectively, and renewables (including solar and wind) made up 12.2 % of capacity, producing just 4.8 % of electricity [3],[4],[5]. Over recent years, Pakistan has witnessed a dramatic shift toward solar imports and installations. Solar panel imports surged from about 2.8 GW in 2022 to roughly 5 GW in 2023. In the first half of 2024 alone, imports topped 13 GW primarily from China for rooftop and off-grid use[6]. By the end of 2024, Pakistan had imported a record-breaking 17 GW of solar panels, doubling 2023's figure and ranking among the world's largest markets[7]. That momentum held into 2025, with net-metering capacity reaching 5.3 GW by mid-year[8]. These trends underscore Pakistan's rapid solarization trend, driven largely by grassroots adoption from households and businesses seeking reliable, affordable energy.

1.2. Current Situation in Pakistan

As of early 2025, solar power accounts for approximately 10% of Pakistan's total renewable electricity generation in grid-connected net-metered capacity [9]. Combined with wind, hydro, nuclear, and biomass, renewables represent about 30% of the nation's energy mix, with solar being the fastest-growing segment.

As of early 2025, solar power has become the fastest-growing segment of Pakistan's renewable energy portfolio. It accounts for approximately 10 percent of the country's renewable electricity generation, with 5.3 GW in grid-connected net-metered capacity. When combined with wind, hydro, nuclear, and biomass, renewables represent about 30 percent of the national energy mix. This growth reflects both utility-scale deployment and the rapid adoption of distributed solar solutions. By the end of 2024, 4.1 GW of rooftop solar was installed across residential, commercial, agricultural, and industrial sectors, a sharp rise from 1.3 GW in mid-2023[10]. Including off-grid applications such as solarized tube-wells, rural schools, and clinics, national solar module imports reached 13–19 GW in 2024, marking a steep acceleration in solar adoption. Table 1 presents an overview of the current status and expansion of solar energy in Pakistan as of early 2025, highlighting key trends in installed capacity, imports, off-grid growth, and alignment with national renewable energy goals.

Table 1 current status and expansion of solar energy in Pakistan.

Category	Key Facts / Figures	Notes / Implications
National lens (2025)	Solar now contributes around 10% of renewable electricity; renewables (solar, wind, hydro, nuclear, biomass) make up ≈30% of Pakistan's energy mix.	Solar remains the fastest-growing segment, reshaping the country's renewable landscape.
Grid Connected Expansion	Solar expanded from <1 GW (2022) to >5 GW (2025); includes 5.3 GW grid-connected net-metered capacity.	Reflects strong growth in both utility-scale and distributed systems nationwide.
Rooftop and Distributed Solar	4.1 GW installed by end-2024 (up from 1.3 GW in mid-2023); rapid uptake in homes, industries, and agriculture.	Signals a structural shift toward consumer-driven and decentralized energy generation.
Off-Grid Expansion	Solar module imports reached ≈17 GW in 2024, driven by off-grid systems such as solar tube-wells, rural schools, clinics, and mini-grids.	Demonstrates widespread adoption beyond urban centers; accelerates rural electrification and climate resilience.
Investment and Growth Momentum	Pipeline includes multiple 100–600 MW projects under public-private and CPEC frameworks.	Sustained momentum toward large-scale solar integration and reduced reliance on fossil fuels.
Strategic Impact	Solar replacing diesel, furnace oil, and LNG generation; reducing import bills and improving grid reliability.	Enhances affordability, energy independence, and emission reduction progress.
Alignment with TARA Objectives	Emphasizes PV and hybrid renewable energy systems for clean grid, affordability, reliability, and access for underserved areas.	Supports Pakistan's transition toward a sustainable, inclusive, and low-carbon power sector.

Punjab has emerged as the center of Pakistan's utility-scale solar expansion. The province hosts over 300 MW of operational capacity, with the Quaid-e-Azam Solar Park in Bahawalpur as its flagship project. Commissioned in 2015 with a 100 MW first phase. Several other utility-scale plants in southern Punjab, including in Bahawalpur and Muzaffargarh, contribute to the province's leadership in solar deployment. A 600 MW photovoltaic project in Muzaffargarh is under development but has faced bidding delays[11]. Punjab's policy environment and flat terrain have made it the testing ground for early solar adoption, especially for grid-scale applications.

Sindh is rapidly establishing itself as the hub of private-sector and hybrid renewable investments. K-Electric is deploying 120 MW and 150 MW solar farms in the province, along with a 220 MW hybrid solar-wind project at Dhabeji. Under the World Bank-supported Sindh Solar Energy Project, the province is adding around 400 MW through a mix of rooftop and grid-scale installations, targeting industrial clusters and public buildings[12]. Sindh's high solar

irradiation and coastal wind resources make it an ideal site for hybrid systems, which help stabilize supply to the Karachi grid and displace costly LNG-based peak power[13].

Khyber Pakhtunkhwa (KP), while lagging behind Punjab and Sindh in large-scale projects, is increasingly turning to distributed and hybrid solar applications. The province is piloting off-grid mini-grids, solarized public buildings, and small hybrid solar-hydro schemes in remote areas. In addition, 200 MW of solar capacity near Dera Ismail Khan has been proposed under CPEC, signaling a shift toward larger investments in the province's southern districts, where grid access is stronger[14]. KP's strategy leverages its abundant hydropower potential to pair with solar for more reliable and balanced energy delivery.

CPEC-backed solar projects continue to be the cornerstone of Pakistan's utility-scale solar growth. Beyond the Quaid-e-Azam Solar Park expansion, new phases include Thal Nova (500 MW) in Punjab, Gwadar Solar Park (300 MW) in Balochistan, and the Dera Ismail Khan solar plant (200 MW) in KP. These projects are strategically designed to displace high-cost fossil-fuel generation, particularly diesel, furnace-oil, and coal plants, reducing Pakistan's peak-time reliance on imported LNG and debt-laden thermal assets.

Pakistan has scaled its solar footprint from under 1 GW in 2022 to over 5 GW by 2025, propelled by a combination of mega-parks, distributed rooftop systems, and CPEC-aligned utility projects. The pipeline of 100 MW to 600 MW projects demonstrates sustained momentum toward a cleaner and more cost-competitive energy mix. This trajectory aligns closely with TARA objectives, it leverages technology adoption through modern PV and hybrid systems, enhances affordability by displacing high-cost fossil fuels, improves reliability with diversified and decentralized generation, and expands accessibility by extending solar solutions to remote and underserved regions. By reinforcing these pillars, Pakistan's solar expansion not only supports emission-reduction targets and energy-security goals but also accelerates the country's transition toward a sustainable and inclusive power sector. The overall, Pakistan solar energy market trends and installed capacity growth is presented in Table 2.

Table 2 Pakistan solar energy market trends and installed capacity growth.

Aspect	Current Trend	Details
Utility Sector Outlook	Poised to lead solar growth, driven by declining module costs and government support.	Forecasted dominance in the utility-scale segment, supported by falling prices and upcoming projects.
Government Targets & Policies	Targeting 30% power from renewables by 2030; supportive policies include net metering, duty exemptions.	Plans of solar-specific auction schemes aim to boost utility-scale deployment.
Installed Capacity (2022)	~600–700 MW (official grid-connected). Imports ~2.8 GW, mostly rooftop/off-grid.	Modest base year, with small-scale installations leading growth.

Installed Capacity (2023)	~1.2 GW grid-connected; imports ~5 GW.	Utility projects (Lucky Cement 26 MW, others) added; distributed solar surged.
Installed Capacity (2024)	Imports ~17 GW (record), net metering ~4–5 GW; total installed >7–8 GW.	Huge jump due to rooftop/off-grid systems; utility-scale still under 1 GW.
Installed Capacity (2025)	Mid-2025: net metering ~5.3 GW; total installed ~9–10 GW.	Solar accounted for ~25% of electricity generation; imports continued strong.
Major Milestones	- 26 MW n-type PV plant at Lucky Cement (2023)- 500 MW JV by Hanersun & My Energy (2024)	JA Solar n-type modules; Hanersun-My Energy partnership with ~USD 700M investment.
Solar's Rising Share	Solar accounted for ~25.3% of electricity in early 2025—surpassing coal, gas, nuclear.	Rapid surge from 2023 to mid-2025; now top electricity source.
Import Trends	Massive imports: ~2.8 GW (2022), ~5 GW (2023), ~17 GW (2024), strong 2025 momentum.	Mainly rooftop & off-grid; China dominant supplier.
Distributed vs Utility	Distributed solar (~7–9 GW) vastly outpaces utility (~500–700 MW) as of 2024–2025.	Driven by households, industry, and commercial rooftops.
Grid Impacts & Inequality	Solar boom benefits affluent and off-grid users but strains grid finance and burden low-income users.	Rising tariffs, restructuring of net-metering, need for equitable policies.
Technologies & Storage	Growing interest in storage solutions, e.g., Lucky Cement's 20.7 MW battery system by CATL to integrate solar.	Battery systems from China helping manage variability and reduce fossil-fuel reliance.

1.3. Pakistan Solar Energy Market Trends

The utility sector with self-effort dominating the solar energy market in Pakistan over the coming years. Solar energy, which involves converting sunlight into electricity using either photovoltaic (PV) or concentrated solar power systems, is becoming increasingly cost-effective due to the declining prices of solar modules and the rise in large-scale project implementations. Pakistan's government has set ambitious targets, such as deriving 30% of its electricity from renewable sources by 2030. Through the Alternative Energy Development Board (AEDB), efforts are underway to expand solar infrastructure nationwide. According to the International[15,16].

Several recent projects highlight the market's momentum. In December 2023, Orient Energy Systems and JA Solar announced the completion of Pakistan's first utility-scale photovoltaic power plant using n-type high-efficiency modules[17,18]. This 26 MW project, located at the Lucky Cement plant, demonstrates the growing scale and efficiency of solar deployment. Further expanding capacity, Hanersun Technologies signed an agreement with local company My Energy in March 2024 to construct a 500 MW solar system, with an estimated investment of USD 700 million[19],[20],[21]. Backed by government support and driven by falling costs, such initiatives are solidifying the utility sector's leading role in the solar market's expansion.

ADS's research reinforces these developments, highlighting that the adoption of high-efficiency solar panels are the only accelerating capacity expansion solution and helpful for reshaping project Pakistan's economics. In particular, our findings emphasize the cost-competitiveness of efficient PV modules in large utility-scale industrial deployments and the significant reduction in levelized cost of energy (LCOE) achieved when such projects are integrated with optimized grid management solutions. By correlating with the ongoing investments in Pakistan, our analysis suggests that scaling beyond pilot projects will further validate the long-term financial and environmental benefits. These insights directly support ADS research outcomes, underscoring the importance of technology choice, investment models, and policy frameworks in driving sustainable solar market growth.

1.4. Industry Uptake and Government Target

Government policies have played a crucial role in accelerating solar adoption across sectors in Pakistan. A significant focus has been placed on shifting public buildings, agriculture (particularly tube wells), and industrial operations from diesel-based systems to solar energy. This shift also aims to replace traditional fossil-fuel-based power plants that rely on diesel, coal, and furnace oil. Solar PV made its entry into Pakistan's energy mix in 2013 after the government introduced policies supporting renewable energy growth. With an average solar irradiance of 9.5 hours per day, the country holds considerable solar potential[22].

According to the Private Power and Infrastructure Board (PPIB), seven solar projects with a combined capacity of 530 MW are already operational and supplying energy to the national grid[23]. As of 2023, solar contributed approximately 8.7% to Pakistan's total renewable energy capacity a figure expected to grow due to continued policy support. The National Solar Energy Initiative, launched in September 2022, aimed to generate 10,000 MW through solar projects, reducing reliance on imported fossil fuels and lowering the energy bill. Moreover, in August 2023, the government announced a solar PV auction plan targeting 9 gigawatts of new capacity, including 6 GW of utility-scale projects, 2 GW of medium-scale systems, and 1 GW of rooftop solar[24,25]. These comprehensive measures are expected to significantly boost the solar share in the national energy mix over the next decade.

Industrial Uptake on Solar Energy: In Sundar Industrial Estate (near Lahore), around 20 MW of industrial power load has already been shifted to solar energy to counter rising electricity costs. In Punjab's industrial sector, both SMEs and large-scale manufacturing units, especially in textiles and cement are adopting solar solutions:

- Roughly 1 in 5 units in the Sundar Industrial Estate, Lahore has transitioned to solar.
- Among roughly 300 textile mills, about 60 mills have partially solarized sections of their operations.
- Solar energy production costs (Rs18/kWh) are significantly lower than grid electricity (Rs40/kWh), making solar highly competitive.

On the large-scale side, Lucky Cement's Nooriabad plant (5 million tonnes/year capacity) now satisfies more than half its electricity requirements with solar and wind. It's also adding a 20.7 MW (22.7 MWh) battery storage system—the largest in the country—to smooth intermittency. Across the board, solar plus battery systems are enabling factories, businesses, and wealthier households to bypass grid unreliability and reduce fuel costs. Demand for such systems has surged, supported by plummeting prices of batteries and panels.

Government's Target Duration: Pakistan's government has introduced several solar-related targets with defined timelines:

Under the Alternative and Renewable Energy Policy (2019):

- Aimed for 30% of power generation (excluding large hydro) from renewables by 2030.
- Interim target of 20% by 2025

The Decade of Solar Energy Initiative launched in September 2022 set out to deploy 10,000 MW of solar, though progress has been mixed.

The Indicative Generation Capacity Expansion Plan (IGCEP) projects:

- Annual additions of solar PV from 2024 through 2031.
- A total of 8,564 MW of solar PV is expected to be added between 2024 and 2031

The National Solar PV auction (Aug 2023) proposed adding 9 GW of solar capacity (6 GW utility-scale, 2 GW medium-scale, 1 GW rooftop), though a specific deadline wasn't explicitly mentioned. However, it's reasonable to assume implementation aims to complete by the end of this decade.

Historically, the Alternative Energy Development Board (AEDB), now merged into PPIB had a target to have 5% of total national power generation from renewables by 2030.

The Indicative Generation Capacity Expansion Plan 2024–34 forecasts that by 2034, renewables will contribute 55% of installed capacity, with 73% of total generation coming from clean sources including hydro.

Chapter 2

Methodology

1.5. Study Design and Objectives

This study, conducted by the ADS, focuses on understanding the dynamics of solar energy adoption within Pakistan's industrial sector. The primary objective is to explore the business strategies, financing models, and market challenges faced by solar companies operating in Pakistan. The study aims to provide insights that contribute to the broader discourse on clean energy adoption in the industrial sector. To achieve this, a comprehensive questionnaire was designed to collect data from solar companies across seven major cities in Pakistan: Lahore, Islamabad, Rawalpindi Faisalabad, Multan, Peshawar, and Karachi.

1.6. Data Collection Approach

1.6.1. Questionnaire Development

A structured questionnaire was developed to gather detailed information from solar companies. The questionnaire, administered through Google Forms, consisted of 32 questions covering various aspects such as company background, core services, installed solar capacity, technical and financial considerations for industrial clients, policy and regulatory challenges, and emerging trends in the solar industry. The questions were a mix of multiple-choice, checkbox, and open-ended formats to capture both quantitative and qualitative data. The questionnaire was designed to align with the study's objectives, drawing on insights from the academic literature review and the current solar energy landscape in Pakistan as outlined in this report.

1.6.2. Sampling Strategy

The study targeted a sample of 20 solar companies from each of the seven selected cities, resulting in a target sample size of 140 companies. These cities were chosen due to their significant industrial activity and prominence in Pakistan's solar energy market. The selection of companies was based on a purposive sampling approach, focusing on firms actively engaged in solar energy solutions, including installation, design, consultation, maintenance, and financing. A list of solar companies was compiled using publicly available data, Google search and Google Maps, online directories, industry reports, and government records from the AEDB and the PPIB.

1.6.3. Data Collection Process

Data was conducted in June and July 2025, during which one enumerator was assigned to each of the seven cities to ensure localized and efficient data gathering. Each enumerator was responsible for contacting and interviewing representatives from the targeted solar companies. The enumerators were trained to administer the questionnaire, either through in-person visits or virtual interviews, depending on the availability and preference of the respondents. The Google Forms platform facilitated real-time data submission and ensured consistency in data entry across all cities.

1.7. Challenges Encountered

Several challenges were encountered during the data collection process, which impacted the efficiency and completeness of the study:

Hot Weather Conditions: The data collection period coincided with high summer temperatures in Pakistan, particularly in June and July 2025. This posed logistical difficulties for enumerators, as fieldwork in cities like Multan, Lahore, Faisalabad, and Karachi was physically demanding due to extreme heat, potentially affecting the pace of data collection.

Discrepancies in Company Locations: In several instances, enumerators found that some companies listed in directories or online maps were not physically present at their registered addresses. This issue was particularly prevalent in Sialkot and Lahore, where outdated or inaccurate information led to delays in locating and contacting the relevant firms.

Lack of Appointment Mechanisms: Most solar companies lacked formal appointment systems, making it challenging for enumerators to schedule visits. Upon arriving at company premises, enumerators often faced the unavailability of relevant staff, such as technical or managerial personnel, who could provide accurate responses to the questionnaire. This issue was more pronounced in smaller firms in cities like Rawalpindi and Multan.

Respondent Availability and Cooperation: Some companies were hesitant to participate due to time constraints or concerns about sharing business-sensitive information, despite assurances that the study was purely academic. This reluctance occasionally resulted in incomplete responses or refusals to participate, particularly in Karachi and Faisalabad.

To mitigate these challenges, enumerators adopted flexible strategies, such as follow-up calls to reschedule visits, leveraging local contacts to verify company locations, and providing clear explanations of the study's academic purpose to build trust with respondents. Despite these efforts, the final sample size was slightly below the target of 150, with approximately 140 completed questionnaires collected due to the aforementioned challenges.

1.8. Data Analysis Plan

The collected data has been analyzed using a mixed-methods approach to address the study's objectives. Quantitative data, such as installed solar capacity, company experience, and preferences for solar panel types, will be analyzed using descriptive statistics to identify trends and patterns. Qualitative data, including responses to open-ended questions about challenges and strategies, will be subjected to thematic analysis to uncover key themes related to business models, financing, and regulatory barriers. The analysis will draw comparisons across the seven cities to identify regional variations in solar adoption practices. The findings will be triangulated with insights from the literature review and the broader solar energy trends in Pakistan to ensure a robust and comprehensive analysis.

1.9. Ethical Considerations

The study adhered to strict ethical guidelines to ensure the integrity of the research process. Participation in the study was voluntary, and respondents were informed of the academic nature of the research and the confidentiality of their responses. No personally identifiable information was collected beyond what was necessary for the study (e.g., company name, respondent's

name, and contact details). Data was stored securely on the Google Forms platform, accessible only to the ADS research team. Enumerators were trained to maintain professionalism and respect the privacy and time constraints of respondents.

1.10. Limitations

The methodology has certain limitations that need to be acknowledged. The purposive sampling approach, while effective for targeting relevant companies, may not fully represent the diversity of Pakistan's solar industry, particularly smaller or emerging firms in less urbanized areas. The challenges encountered during data collection, such as incomplete responses and difficulties in locating companies, may introduce minor biases in the dataset. Additionally, the reliance on Google Forms assumes a certain level of digital literacy among respondents, which could exclude some smaller firms with limited technological access. Despite these limitations, the methodology is designed to provide a comprehensive and representative snapshot of industrial solar adoption in Pakistan's major cities.

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Chapter 3

Results and Discussions

The survey responses provide a comprehensive overview of the current landscape, challenges, and opportunities in the industrial solar sector from the perspective of solution providers. The data reveals that industrial clients are increasingly favoring high-efficiency technologies like N-type panels and are primarily driven by financial benefits such as ROI, operational savings, and net metering. At the same time, technical considerations like panel efficiency, system lifespan, and energy consumption heavily influence decision-making. While financial motivators and sustainability goals encourage adoption, barriers such as high upfront costs, regulatory delays, and inconsistent government policies remain significant hurdles. Companies are responding by offering tailored business models, effective client education strategies, after-sales services, and innovative partnerships to enhance engagement and market reach. Additionally, emerging trends such as advanced panel technologies, energy storage, and smart grid integration are seen as key drivers of future growth in this sector. Overall, the findings of 140 surveys reflect a dynamic shift toward more clean energy, consumer benefit, and policy-sensitive approaches in industrial solar deployment. The detailed analyses provided below:

This pie chart in Fig. 1 represents the experience in the solar business. Here's a brief analysis: Firstly, from 2–5 years: the largest group, making up 41.4%, suggests that many companies are relatively young but have had time to establish themselves in the market. Secondly, from 6–10 years: comprising 36.4%, this group also shows a strong presence of maturing companies with moderate experience. Thirdly, over 10 years: 14.3% of companies have significant long-term experience, reflecting a smaller, more seasoned segment of the industry. Lastly, less than 1 year: only 7.9% are new entrants, indicating limited recent startup activity or higher barriers to entry. Additionally, the solar industry appears to be dominated by relatively young but growing companies (2–10 years of experience), while fewer businesses have either just entered the market or have been in it for over a decade. This suggests a dynamic and maturing industry with a solid base of experienced players.

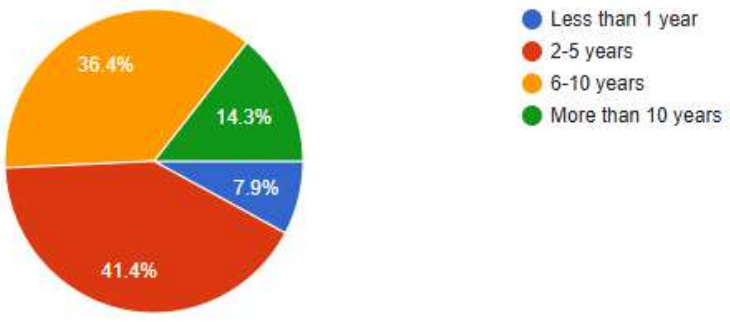

Figure 1 Distribution of company experience in the solar industry.

The chart in Fig. 2 illustrates the core services offered by the solar companies involved in solar installations. Solar panel installation is the most common service, provided by 90.7% of

companies, indicating it as the industry's primary function. Maintenance and after-sales support follow closely, offered by 80.7% of companies, highlighting a strong emphasis on long-term customer support and system performance. Solar system design and consultation is offered by 60.7% companies, showing that a majority also engage in the planning and customization of solar solutions. However, only 30.7% companies provide financing and leasing options, which points to a significant gap in financial service offerings. This suggests that while most companies focus on the technical and service aspects of solar installations, there may be an opportunity for growth in integrated financial solutions to make solar more accessible.

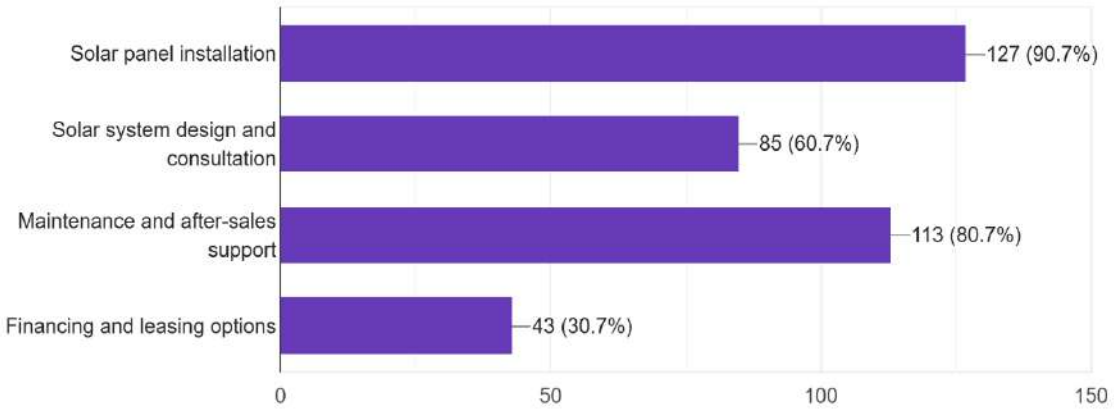

Figure 2 The core services offered by the solar companies.

In Fig. 3, residential is the most commonly served sector with 96.5%. Commercial projects are nearly as prevalent, with 94.3% indicating a strong market for business-related installations. Industrial clients are also a major focus, with 90.8% companies serving this sector, reflecting robust demand for large-scale energy solutions. The agriculture sector, while still significant, is less commonly served, with 74.5% companies indicating potential room for growth in rural or farming-related solar applications. Overall, the data suggests that solar companies maintain a broad and balanced market reach, with slightly less penetration in the agricultural domain.

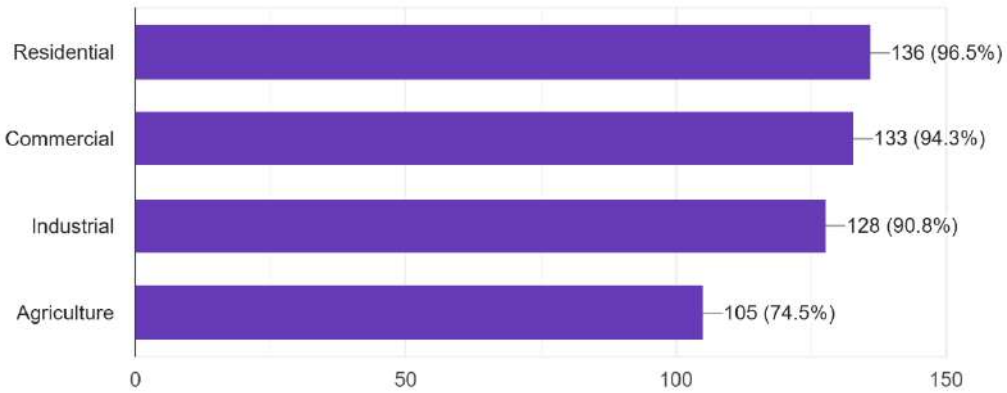

Figure 3 The distribution of sectors served.

Fig. 4 illustrates the total solar capacity installed to date by the companies. The largest proportion, 39.7%, have installed between 6–20 MW, indicating that most companies operate at a mid-scale level. The second most common range is 2–5 MW, with 19.9% of companies falling in this category, suggesting a significant portion are small to medium-sized installers. Additionally, the high-capacity providers are also notable: firstly, 18.4% have installed more than 50 MW, showing a strong presence of large-scale operators in the industry. Secondly, 9.9% report installations in the 21–50 MW range, representing an additional segment of substantial capacity providers. Thirdly, on the smaller end, 12.1% of companies have installed less than 1 MW, highlighting a niche group of either newer entrants or those focused on very localized installations. Lastly, overall, the data reveals a healthy mix of company sizes, with the bulk of activity centered in the 6–20 MW range, pointing to a strong mid-market presence in the solar sector.

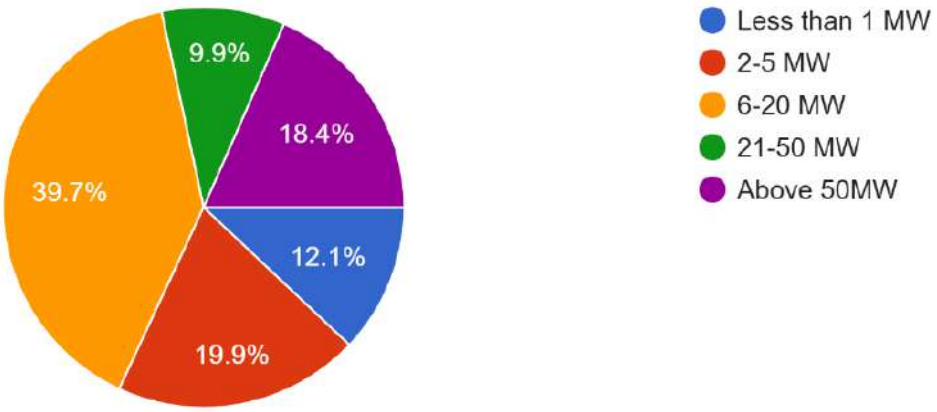

Figure 4 Total solar capacity (in kW/MW) solar companies have installed to date.

This horizontal bar chart in Fig. 5 presents the capacity of solar power installed by the solar companies specifically in the residential sector.

- The largest share of companies 36.7% have installed more than 1000 KW (1 MW), indicating a strong presence of high-capacity installers in residential markets.
- Close behind, 34.5% of solar companies have installed between 500–1000 KW, reflecting a significant segment of mid-scale residential solar providers.

On the lower end:

- 20.9% of companies have installed less than 250 KW, likely representing small-scale or emerging businesses, or those focusing on low-volume residential projects.
- Only 18% of companies fall in the 250–500 KW range, suggesting a relatively smaller presence of companies operating at this capacity level.

Overall, the majority of companies over 70% are installing more than 500 KW in the residential sector, highlighting a trend toward larger-scale residential solar deployment and the increasing maturity of providers in this space.

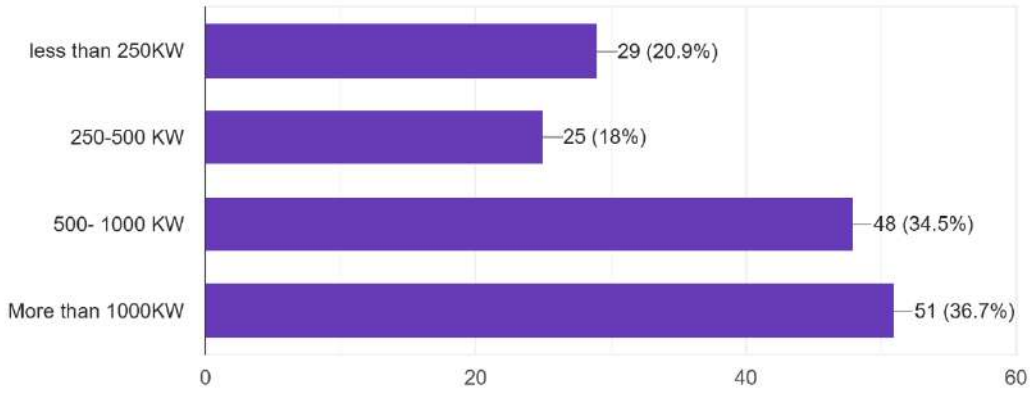

Figure 5 Installed residential solar capacity by the solar companies.

Fig. 6 illustrates the distribution of solar power capacity installed in the commercial sector by the solar companies.

- The largest segment, 42.9% of companies, have installed more than 1000 KW, indicating a strong presence of large-scale commercial solar providers.
- 32.1% of solar companies report installations between 500–1000 KW, showing that nearly a third of companies operate at a mid-range commercial capacity.

Smaller capacity installations are less common:

- 16.4% of the companies have installed 250–500 KW, and
- 15.7% of thecompanies have installed less than 250 KW, likely representing smaller firms or those serving limited commercial markets.

Therefore, over 75% of companies have installed more than 500 KW in the commercial sector, signaling a market dominated by medium- to large-scale projects. This trend reflects the growing demand for solar power in commercial operations, such as offices, retail, and industrial facilities.

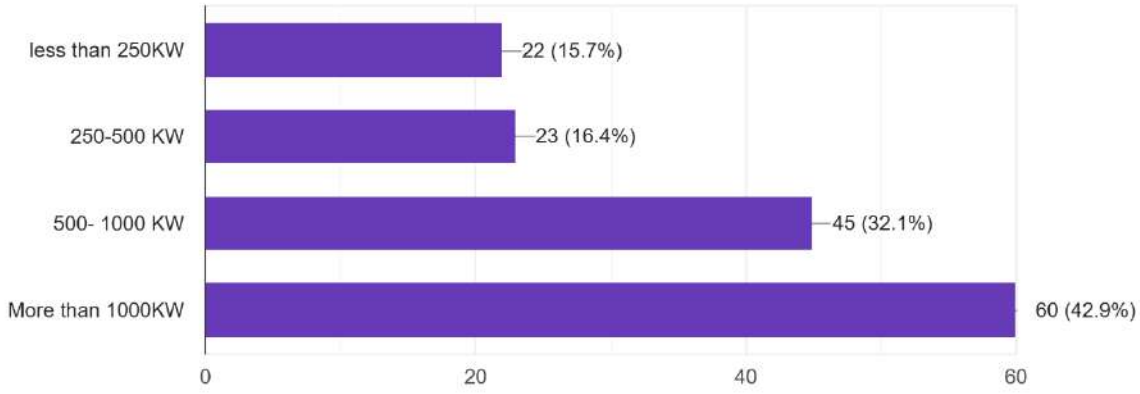

Figure 6 Installed commercial solar capacity by companies.

Fig. 7 shows the installed solar power capacity in the industrial sector by the solar companies.

- A dominant majority, 74.5% off the solar companies), have installed between 1–20 MW, indicating that small- to mid-scale industrial solar projects are the most prevalent in this sector.
- 12.8% of the solar companies have installed 21–50 MW, while 9.2% of the solar companies report installations of 51–71 MW, reflecting a smaller but notable presence of medium-to-large capacity providers.
- 4.3% of the solar companies have installed more than 100 MW, showing that large-scale industrial solar deployment is still relatively limited but present.

Other responses are minimal:

- 1.4% each of the companies indicated no installation or explicitly stated "no installation", and
- 0.7% presents only one solar company marked "not installed" and "400 kW", possibly indicating data entry inconsistencies or anomalies in reporting.

The data suggests that while the industrial solar market is active, it is largely concentrated in the 1–20 MW range, with a smaller share of high-capacity deployments. The lower representation of large-scale installations may point to cost, space, or policy limitations in scaling up industrial solar adoption.

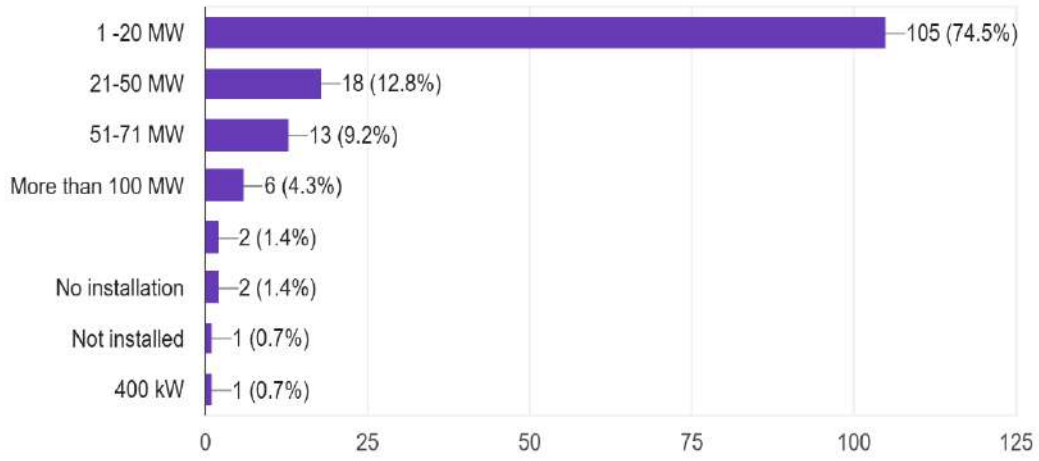

Figure 7 Installed industrial solar capacity by companies.

Fig. 8 summarizes the solar power capacity installed in the agriculture sector by the solar companies.

- The majority, 46.3% of the solar companies, have installed between 1–20 MW, indicating a strong presence of small- to mid-scale solar deployment in agricultural settings.
- 36% of the companies have installed less than 1 MW, reflecting a sizable group likely engaged in small or pilot projects tailored to farms or rural setups.

- Only 3.7% companies reported installations in the 21–50 MW range, while a single company (0.7%) reported installing more than 50 MW, suggesting that large-scale agricultural solar projects are rare.

A notable portion of companies indicated no activity in the agriculture sector:

- 8.1% of the solar companies reported "Nil" installations,
- 2.2% of the solar companies selected "No installation", and
- 0.7% responded with "No", "No Installation in Agriculture Sector", and miscellaneous non-installation responses likely due to inconsistent data entry.

Therefore, the data highlights that while over 80% of companies have some level of solar installation in the agricultural sector, activity is largely concentrated in small- to medium-capacity projects, with limited engagement in large-scale installations. This suggests a growing but still emerging opportunity in agricultural solar markets.

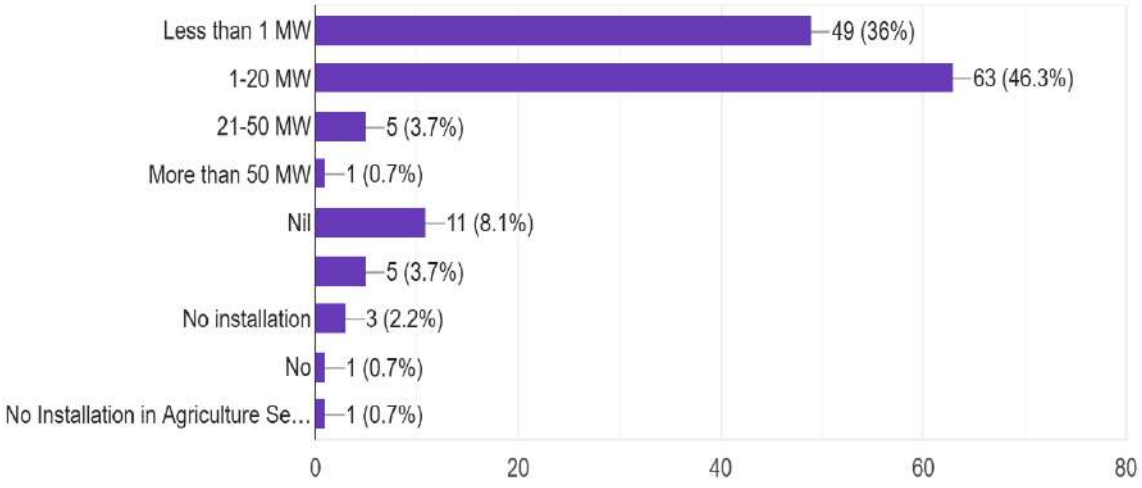

Figure 8 Installed agricultural solar capacity by companies.

Fig. 9 presents the distribution of industrial sectors served by the solar companies involved in solar installations.

- The Food and Beverages sector is the most served, with 59.7% implemented solar, reflecting the sector's high energy demands and suitability for solar power.
- Close behind, Textile industry clients account for 57.6%, indicating significant adoption of solar power in manufacturing and production facilities.
- Leather and sports have lower representation, with 17.3% of the solar companies and 15.1% of the solar companies, respectively, showing some diversification into niche industrial segments.
- A notable 32.4% serve a broader category likely encompassing other miscellaneous industries or mixed industrial applications.

The remaining responses mostly represent other sectors with capacity of 0.7%, including industries like education institutions, hospitals, rice mills, poultry farms, IT, and bottle

manufacturing, among others. Some companies also indicated serving all types of industries or did not specify installation. Additionally, the data shows that the industrial solar market is heavily implemented in food & beverages and textiles, with smaller but varied participation across other sectors, pointing to opportunities for expanding solar solutions into less served industries.

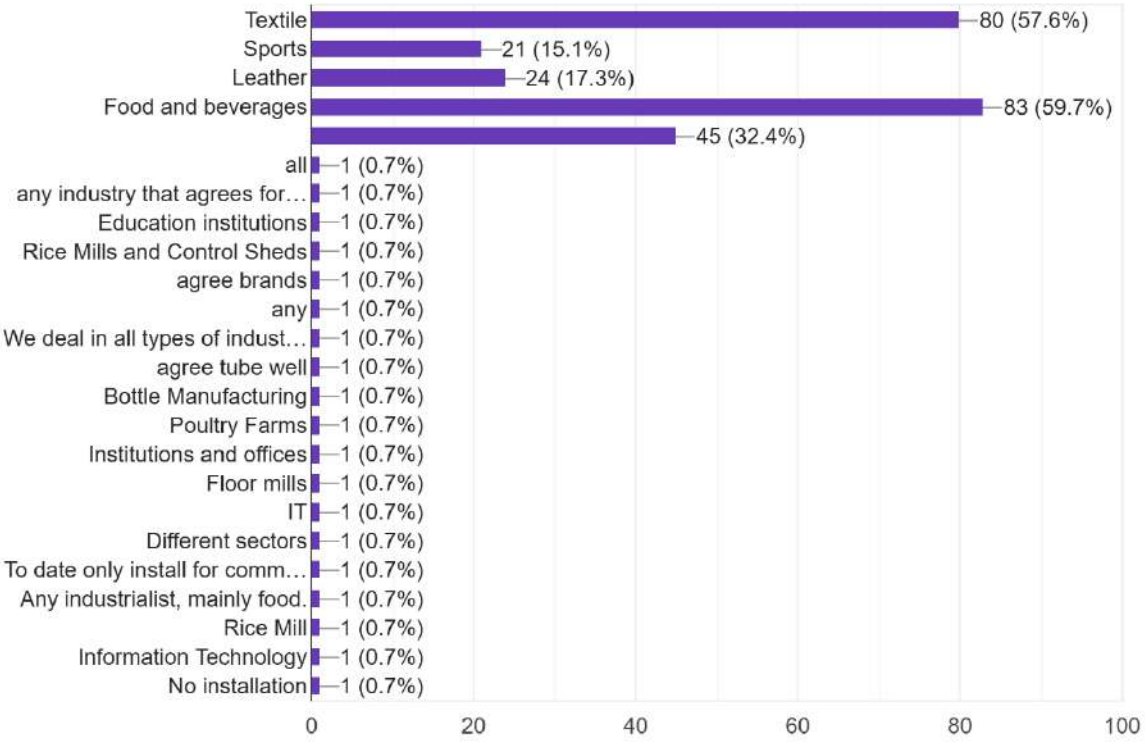

Figure 9 Industrial sectors served by companies in solar installations.

Fig. 10 illustrates different industrialists have different preferences regarding different types of solar panels.

- N Type panels are overwhelmingly preferred, with 95% favoring this type, indicating strong market dominance likely due to higher efficiency or better performance.
- P Type panels come next, favored by 31.9%, showing a significant minority still choose this type.
- Among panel technologies, Monocrystalline panels are preferred by 12.8%, while Polycrystalline panels have a lower preference at 6.4%.
- Hybrid panels have a moderate preference of 9.2%.
- Thin-film panels are the least favored among the main categories, with only 2.1% selecting them.
- Additionally, a few respondents mentioned Bifacial panels and gave comments such as preferring P type before 2 years or N type because of availability, each making up 0.7%.

Additionally, the data highlights a clear industrial preference for N Type solar panels, with varied but significantly lower interest in other types, reflecting performance and market trends in solar panel technology.

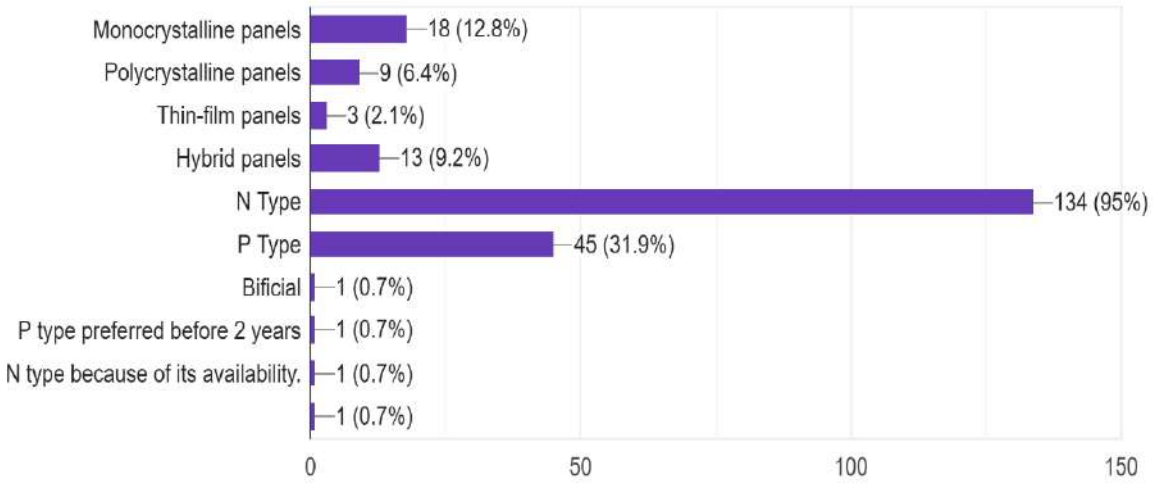

Figure 10 Preferred types of solar panels by industrialists

Fig. 11 summarizes the responses of the industrialists regarding the technical factors that motivate them to undertake large-scale solar power installations.

- The most important consideration is Panel Efficiency, with 80.1% indicating it as a key factor. This highlights the priority placed on maximizing energy output.
- System Lifespan is the second most cited factor, with 71.6%, reflecting concerns about the durability and long-term reliability of solar installations.
- Energy Consumption is also a significant driver, chosen by 68.1%, showing that industrialists align installations with their energy needs.
- Panel Quality is important to 52.5%, emphasizing the role of build and material standards in decision-making.
- Regulatory Compliance influences 40.4%, underlining the importance of adhering to legal and policy frameworks.
- The least prioritized factor is Location, with 30.5%, suggesting that while site suitability matters, it is not the primary concern.

The technical factors related to panel performance, durability, and energy demand are paramount for industrialists when considering large-scale solar projects. Regulatory and locational aspects also play roles but to a lesser extent.

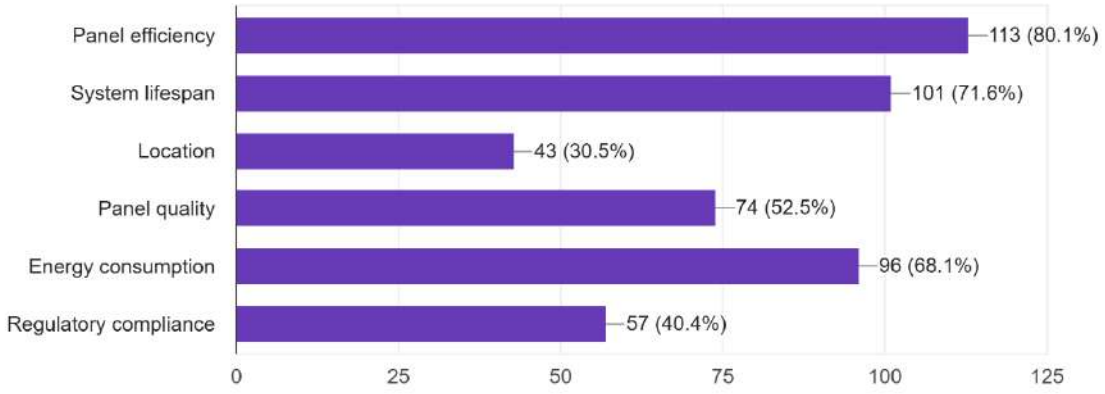

Figure 11 Technical considerations encouraging industrialists for large-scale solar.

Fig. 12 presents the financial factors that influence industrialists when planning large-scale solar power installations.

- The top three financial considerations are almost equally important:
  - Net Metering is the leading factor, with 64.5% highlighting its role in financial feasibility.
  - Both Return on Investment (ROI) and Operational Savings are cited by 63.8%, showing that profitability and cost reductions are critical motivators.
- Green Branding appeals to 43.3%, indicating that corporate social responsibility and sustainable image also impact financial decisions.
- Government Subsidies are considered by 23.4%, suggesting moderate influence from policy incentives.
- Uninterrupted Supply ranks lowest at 21.3% respondents, which may indicate that while energy reliability matters, it is less of a financial driver compared to savings and incentives.

Therefore, the industrialists prioritize financial returns, operational cost savings, and net metering benefits when investing in solar installations, while subsidies and branding are secondary considerations.

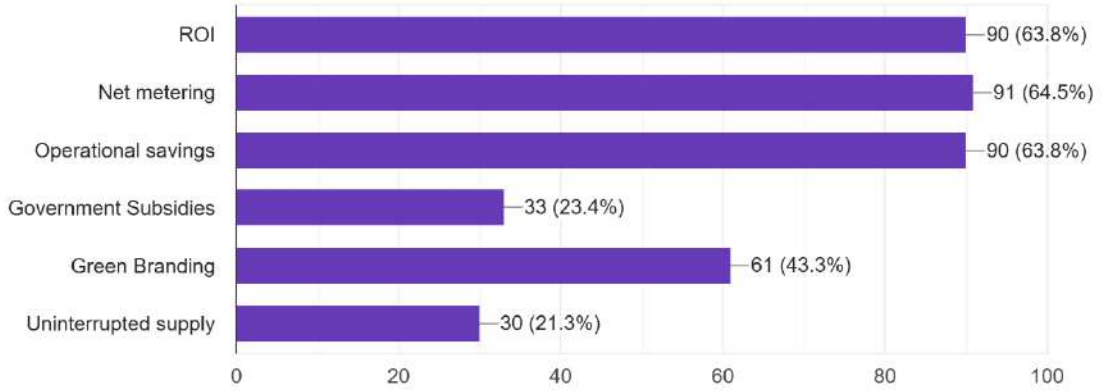

Figure 12 Financial considerations driving industrialists to plan large-scale solar installations.

Fig. 13 highlights the financial barriers perceived by the industrialists when considering large-scale solar installations.

- The most significant discouraging factor is the Upfront Cost, cited by 80.1%, indicating that high initial investment is the major hurdle.
- Total Cost overall is a concern for 51.8%, showing that cumulative expenses beyond just the upfront cost also weigh heavily.
- The Cost of Batteries is a notable concern for 39%, reflecting the expense related to energy storage systems.
- Maintenance Cost is also significant, with 35.5% viewing it as a financial deterrent.
- Net Metering is less discouraging, reported by 31.2%, possibly due to variability or complexity in its implementation.

The high initial and overall costs, including batteries and maintenance, are the primary financial factors discouraging industrialists from investing in large-scale solar projects.

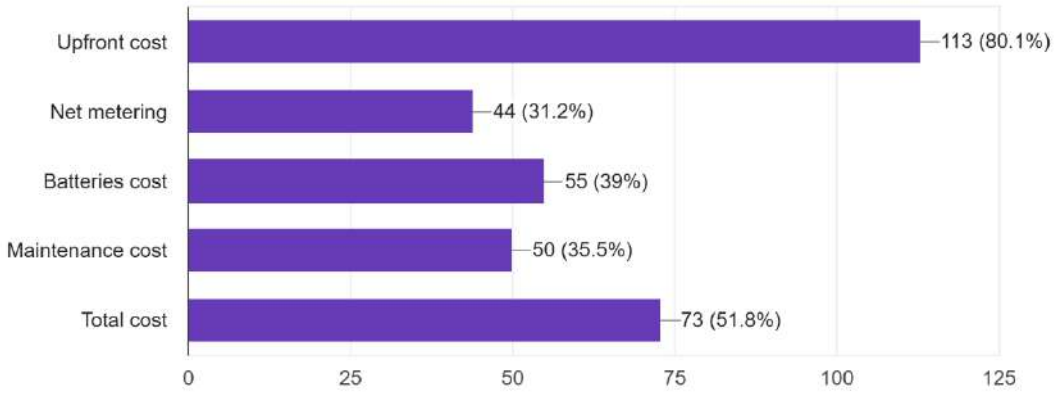

Figure 13 Financial considerations discouraging industrialists from large-scale solar installations.

Fig. 14 reflects the additional non-financial factors motivating the industrialists toward adopting large-scale solar installations:

- The leading consideration is GHG Emissions Reduction, mentioned by 69.2%, indicating a strong commitment to lowering greenhouse gas emissions.
- Environmental Conservation follows closely, with 58.6% highlighting environmental protection as a key factor.
- Compliance with National Regulations (e.g., EPA) is important to 48.1% (64 respondents), showing regulatory adherence plays a major role.
- Carbon Credits are a motivating factor for 39.1%, reflecting interest in financial incentives linked to carbon markets.
- Compliance with International Regulations affects 37.6%, suggesting attention to global standards.
- Following the Trend influences 31.6%, indicating some industrialists are motivated by market momentum or peer actions.

The environmental concerns and regulatory compliance are significant non-financial drivers for industrialists considering large-scale solar projects, with emissions reduction and conservation being top priorities.

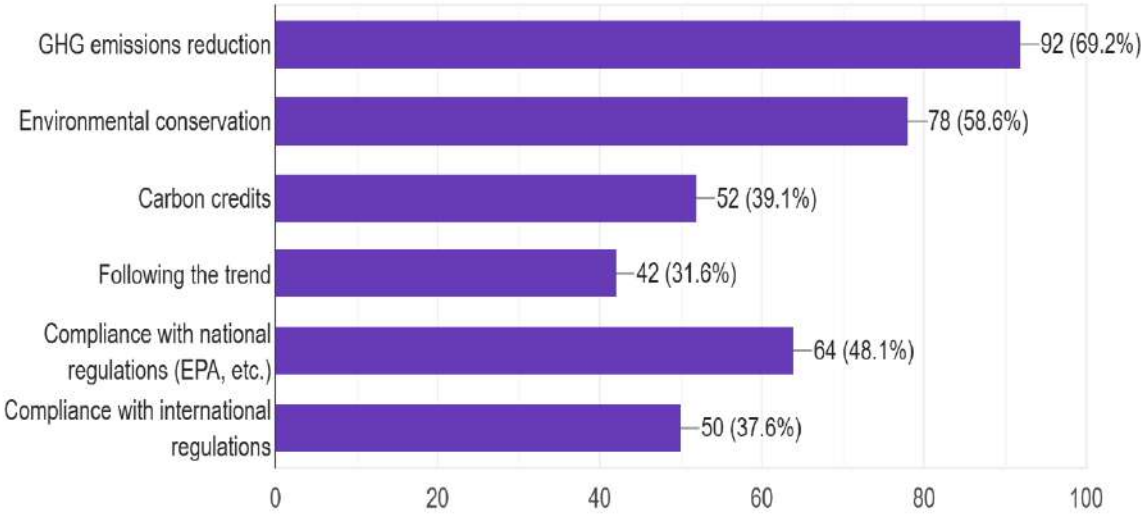

Figure 14 Other considerations influencing industrialists for large-scale solar installations.

The chart of Fig. 15 presents the major challenges encountered by the respondents during the installation of industrial solar projects:

- The most frequently reported challenge is Regulatory Delays, affecting 59.7%, indicating bureaucratic processes significantly hinder project timelines.
- Supply Chain Issues come next, cited by 51.8%, showing that sourcing and logistics remain problematic.
- Installation Space is a concern for 49.6%, highlighting difficulties related to site availability or suitability.
- Client Awareness is reported by 48.2%, reflecting that a lack of knowledge or understanding among clients impacts project implementation.
- Equipment Performance is an issue for 33.8%, suggesting technical reliability or quality concerns.
- Occupational Health and Safety concerns are mentioned by 33.1%, emphasizing the importance of maintaining safe working conditions.
- A smaller portion, 10.1%, report experiencing All of the Above challenges simultaneously.

Therefore, regulatory hurdles, supply chain bottlenecks, and installation space constraints are the top challenges in industrial solar project installations, compounded by client awareness and technical issues.

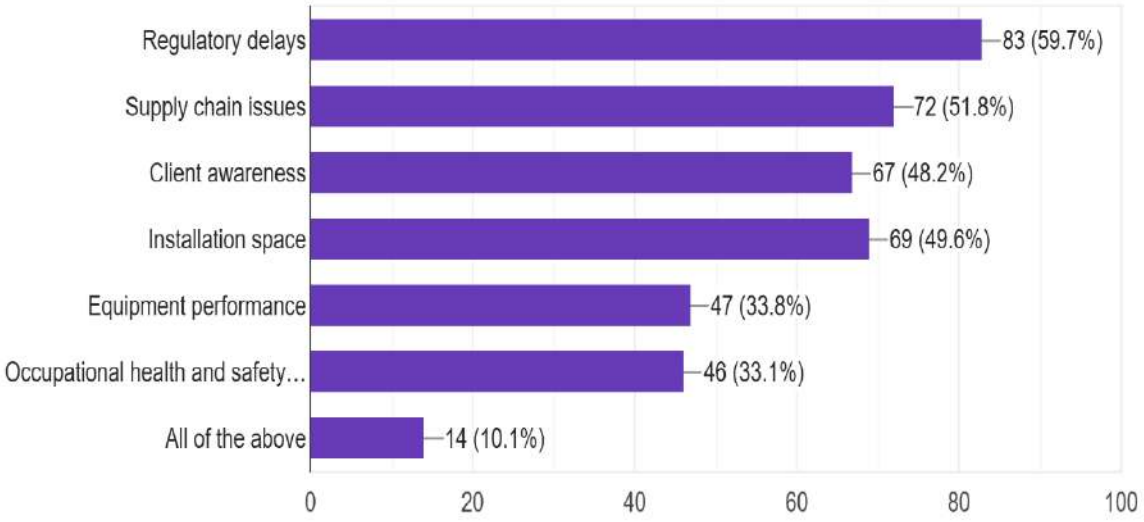

Figure 15 Common challenges faced in installing industrial solar projects.

Fig. 16 displays a pie chart of the solar companies regarding whether they offer business models to their industrial clients:

- A significant majority, 81.2% of companies, responded Yes, indicating they do provide business models to their industrial clients.
- A smaller portion, 18.8%, responded No, meaning they do not offer such business models.

This suggests that most companies recognize the importance of offering tailored business models to industrial clients, potentially to enhance customer engagement, flexibility, and project feasibility.

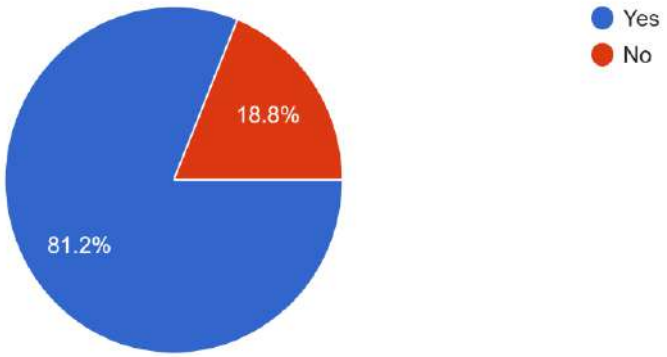

Figure 16 Provision of business models by companies to industrial clients.

Now, Fig. 17 shows the responses of the respondents regarding the strategies they employ to attract industrial clients to solar solutions:

- The most prevalent strategy is highlighting financial benefits such as ROI and cost savings, with 92.9% using this approach. This indicates financial incentives are the primary motivator for industrial clients.

- Offering customized solutions for specific energy needs is also widely used, with 72.9%, showing the importance of tailored solar solutions.
- Emphasizing clean energy and sustainability is used by 67.1%, reflecting a significant focus on environmental benefits.
- The least common strategy is maneuvering existing or upcoming regulatory measures, at 45%, suggesting it is less influential or less commonly used as a client attraction method.

Overall, the emphasis on financial benefits and customization highlights the practical and economic priorities of industrial clients when considering solar installations.

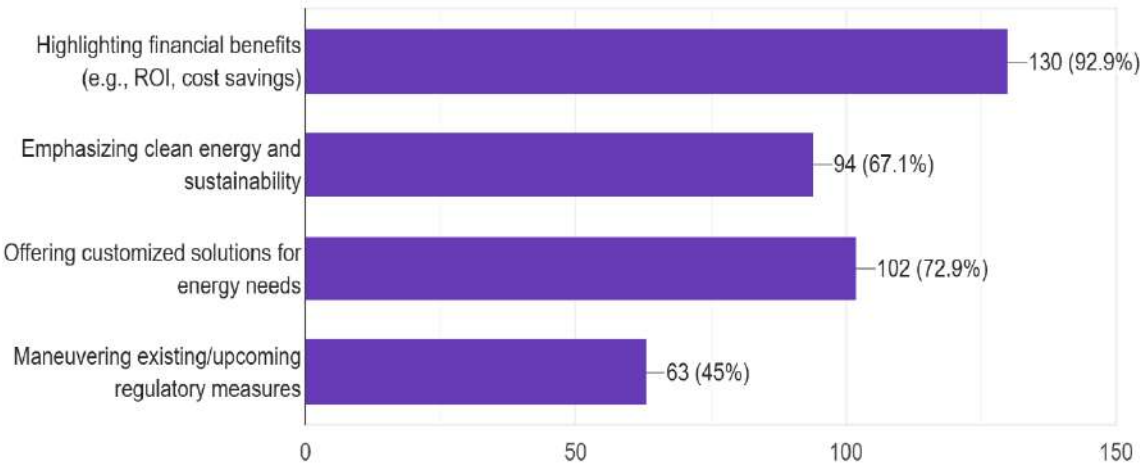

Figure 17 Strategies used to attract industrial clients to solar solutions.

Fig. 18 represents responses from the solar companies respondents on which industrial processes or equipment solar energy is considered less effective for:

- Boilers are seen as the least effective for solar energy, with 60.7%.
- Water pumps follow with 51.9% indicating less effectiveness.
- Motors are reported by 46.7% as less effective for solar.
- Air conditioning systems come next at 42.2%.
- Dyeing and Finishing processes are considered less effective by 40%.
- Very few responses indicate no opinion or other reasons (each about 0.7% to 1.5%).

Solar energy is perceived as less effective primarily for equipment with high continuous energy demand or heat requirements, such as boilers and water pumps. This reflects possible limitations of solar technology in meeting specific industrial energy needs where consistent or high thermal energy is necessary.

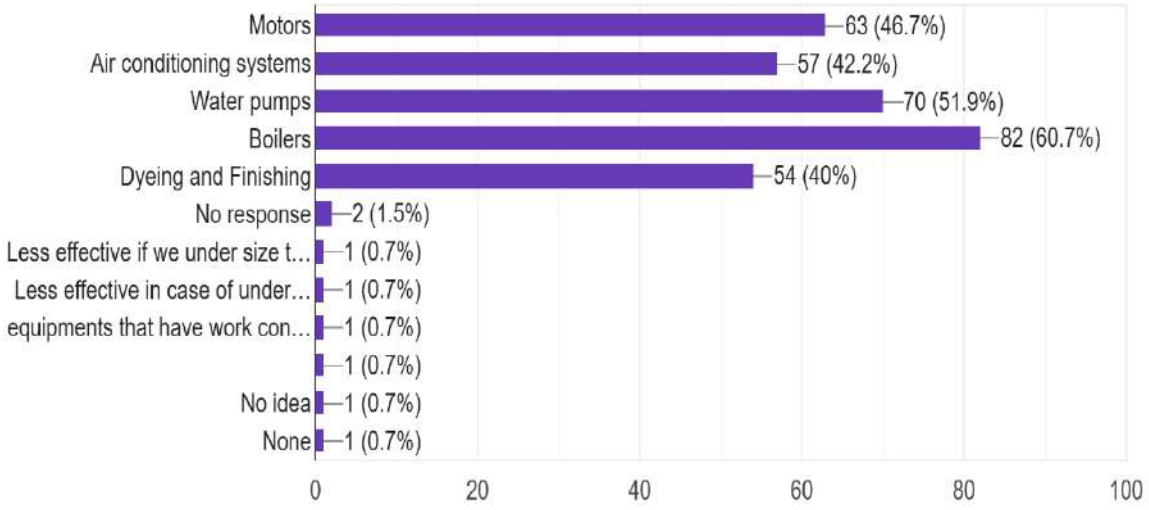

Figure 18 Processes or equipment is solar energy less effective.

Most companies engaging industrial clients for solar solutions rely on formal pitch decks, supplemented by informal discussions and basic business plans. Digital or unconventional marketing tools are less commonly used, and only a few lack formal engagement materials entirely. The results of Fig. 19 suggest the structured presentations remain key in industrial client engagement.

- 78% have a formal pitch deck.
- 54.6% engage clients through informal discussions.
- 51.8% have a basic business plan.
- A small minority:
    - 4.3% use unconventional and digital marketing tools.
    - 3.5% do not have a business plan or pitch deck.

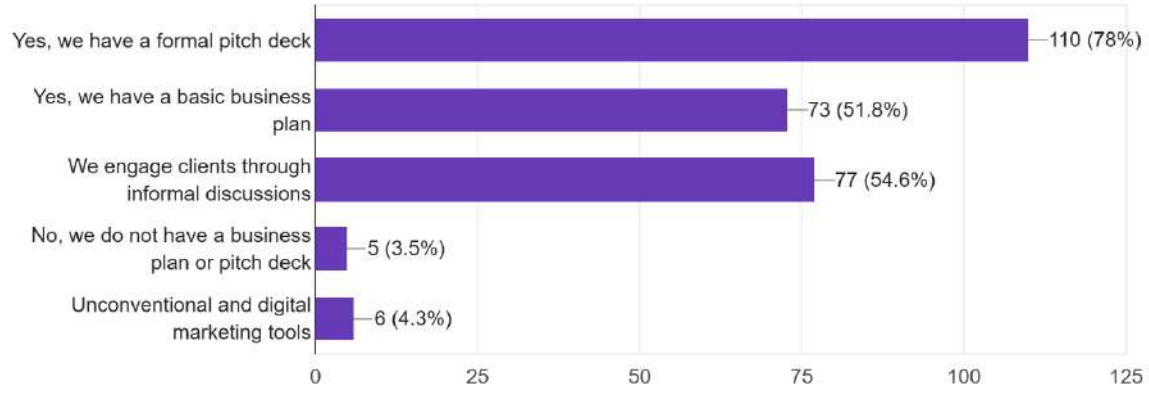

Figure 19 Pitch deck for engaging potential industrial clients.

The data of Fig. 20 reveals that industrial clients are primarily educated about the benefits and potential savings of solar energy through personalized and evidence-based approaches. The two most common methods providing case studies and testimonials, and one-on-one consultations and presentations each account for 46.8% of responses, highlighting the

importance of detailed, tailored information and real-world examples in client education. Additionally, 39.7% of respondents use a combination of all available methods, indicating a multi-faceted approach is also valued. Conversely, webinars and workshops are the least utilized method, at only 12.8%, suggesting these may be less effective or less preferred for this audience. Overall, the data underscores the preference for personalized, credible, and diverse educational strategies when engaging industrial clients on solar energy topics.

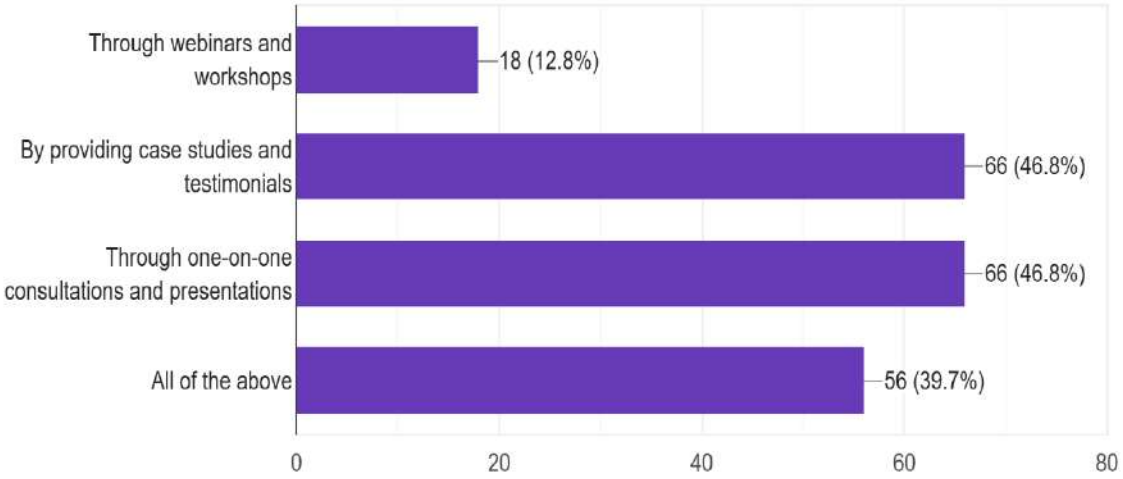

Figure 20 Methods used to educate industrial clients on solar energy benefits and savings.

The results of Fig. 21 indicate that the most commonly offered after-sales service is annual maintenance and system check-ups, with 56.7% of respondents providing this service, emphasizing the importance of regular system upkeep for reliability and performance. Warranty services for parts and labor are also significant, offered by 38.3% of respondents, reflecting a focus on ensuring long-term system support and client confidence. Meanwhile, 24/7 customer support is available from 29.8% of companies, highlighting the value of immediate assistance but showing it is less common compared to other services. Notably, 36.9% offer all of the above, demonstrating a comprehensive approach to client care post-installation. Overall, the data suggests a strong emphasis on maintenance and warranties to ensure system longevity and client satisfaction.

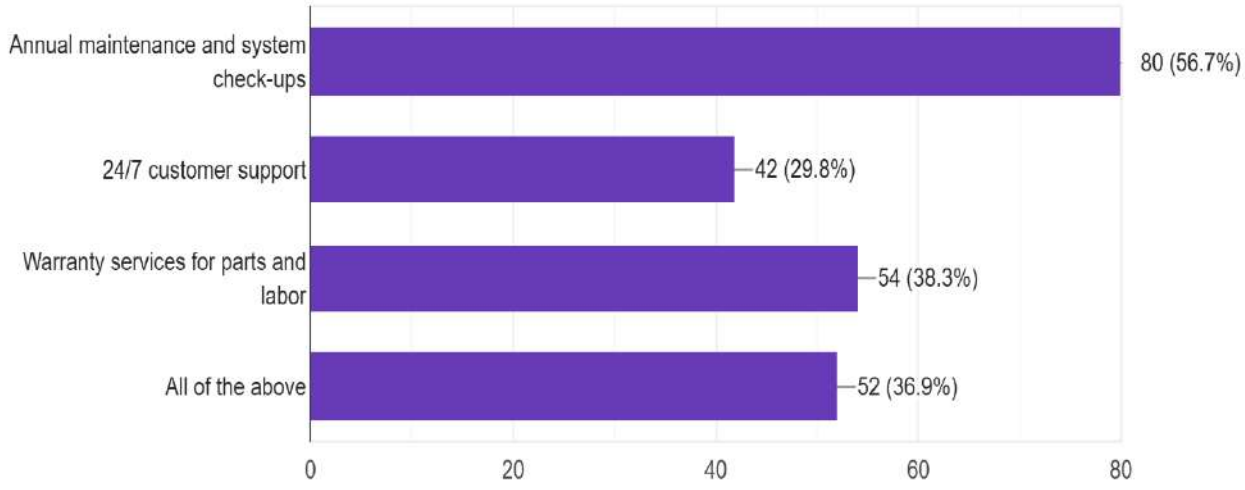

Figure 21 After-sales services and maintenance packages offered to industrial solar clients.

In Fig. 22, the majority of respondents, as 70.7% have multiple case studies and testimonials, demonstrating a strong emphasis on showcasing the positive impact and benefits of their solar solutions through documented evidence. Another 20% of companies have a few case studies available upon request, indicating some level of preparedness but less extensive documentation. A small portion of 2.9% does not have any case studies or testimonials, which might suggest an area for improvement in marketing and client engagement. Additionally, 6.4% are unsure about the availability of such materials, highlighting potential gaps in internal communication or record-keeping. Overall, the data suggests that most companies recognize the importance of using case studies and testimonials as a tool to build credibility and attract industrial clients.

Figure 22 Availability of case studies and testimonials from industrial clients highlighting solar.

The results of the Fig. 23 reveal several significant policy and regulatory challenges that hinder the growth of the industrial solar sector. The most prominent issue, cited by 58.9% of respondents, is the lack of clear regulatory frameworks, indicating a pressing need for more structured and transparent government policies. Delays in permit approvals affect 38.3% of respondents, highlighting bureaucratic inefficiencies that slow project implementation. Nearly half of the respondents 48.9% identify inconsistent taxation policies as a barrier, which adds uncertainty to financial planning. Similarly, 48.2% of respondents are challenged by rapidly

shifting net-metering policies, complicating long-term project viability and investment decisions. Overall, these challenges underscore the importance of stable, transparent, and streamlined regulatory environments to foster industrial solar adoption.

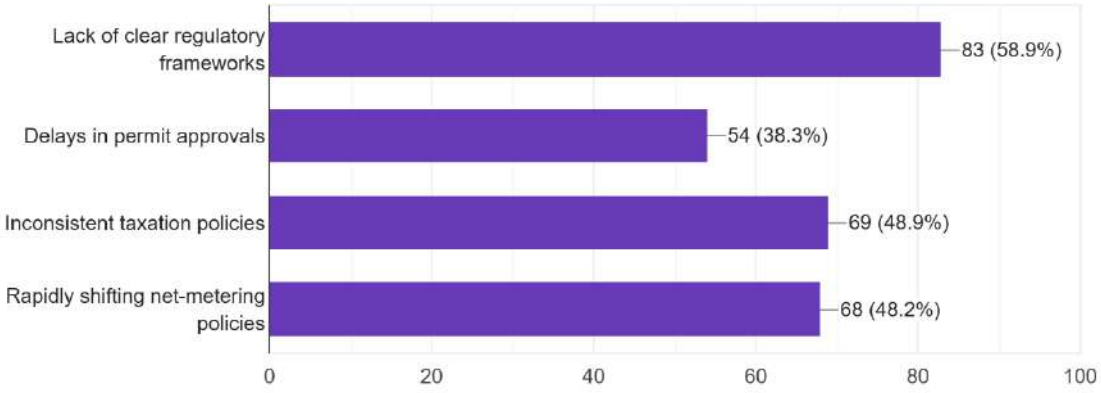

Figure 23 Key policy and regulatory challenges faced by the Industrial sector.

Fig. 24 highlights key policy recommendations to boost industrial solar adoption. The top priority, supported by 72.1% of respondents, is increased tax incentives for solar investments, indicating that financial benefits are crucial for encouraging uptake. Net metering policies also rank highly, with 64.3% seeing them as vital for promoting solar use in industries. Streamlining permit approval processes is important for 33.6%, reflecting ongoing frustrations with bureaucratic delays. Incentivizing grid access for industrial solar users is suggested by 25.7%, emphasizing the need for better integration of solar systems with existing infrastructure. The suggestion for local factories availability was minimally supported by 0.7%, showing lesser focus on domestic manufacturing as a direct policy lever. Overall, financial incentives and regulatory streamlining emerge as the key drivers for improving industrial solar adoption.

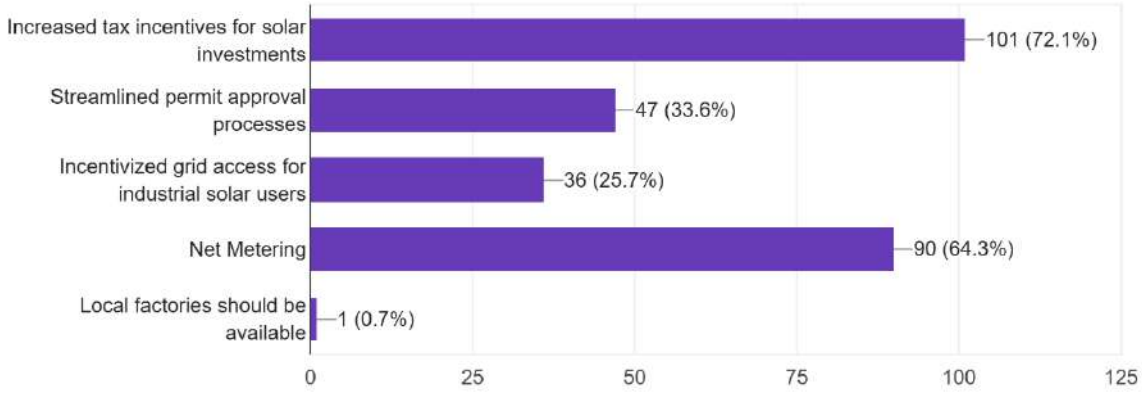

Figure 24 Recommended policies to enhance industrial solar adoption.

The responses analyzed in Fig. 25 indicate a multifaceted approach to ensuring compliance with government solar energy regulations and incentives. The most common method, chosen by 46% of respondents, is employing all listed strategies, demonstrating a comprehensive approach. Regular consultation with legal and regulatory experts is favored by 45.3%, highlighting the importance of specialized knowledge in navigating complex policies. Ongoing training for staff on compliance requirements 32.4% and close monitoring of policy changes

with adaptive measures 31.7% also play significant roles. Overall, a combination of expert advice, continuous education, and proactive policy monitoring is key to maintaining compliance in the evolving solar energy regulatory landscape.

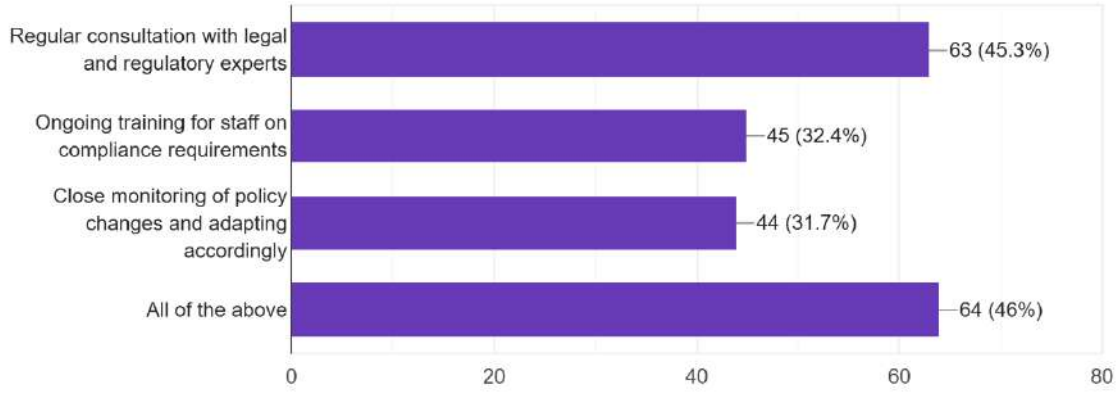

Figure 25 Methods for ensuring compliance with government regulations and incentives in Solar.

In Fig. 26, the responses of the respondents reveal that a majority of respondents recognize multiple emerging technologies as key drivers for the future of industrial solar installations. The highest proportion, 41.4%, believe that a combination of all the listed technologies energy storage solutions like batteries, smart grid integration and IoT-based monitoring, and advanced panel efficiency will collectively shape the industry's future. Individually, advanced panel efficiency is seen as the most influential trend by 40% of respondents, followed closely by energy storage solutions at 35%, and smart grid integration with IoT-based monitoring at 30.7%. This reflects a broad acknowledgment of the importance of both hardware improvements and digital innovations in advancing solar energy for industrial applications.

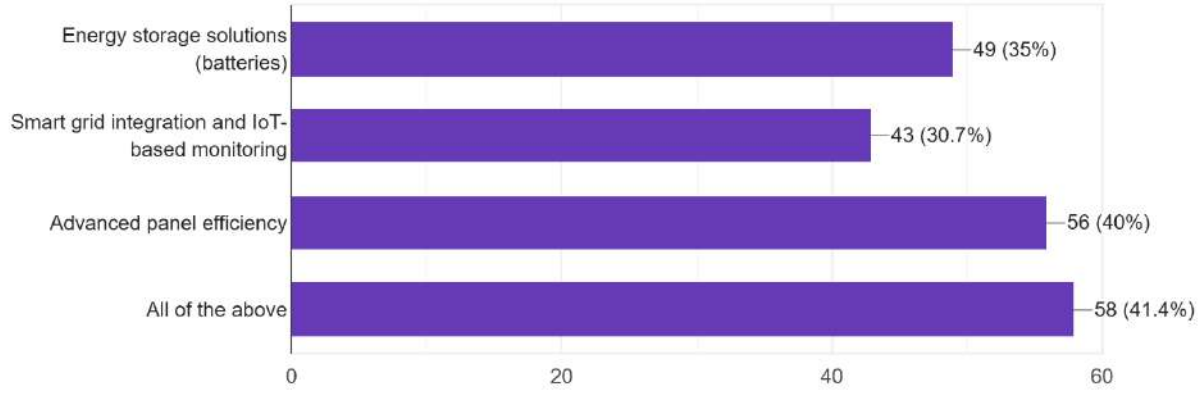

Figure 26 Emerging technologies and trends shaping the future of industrial solar installations.

The responses highlight that nearly half of the respondents 46.7% are exploring a combination of innovative business models and partnerships to expand their company's market reach. Among individual options, collaborations with utility companies for shared energy solutions lead at 29.6%, followed closely by partnerships with financial institutions for improved financing options and exploring community solar programs, both at 26.7%. This suggests that industry players are actively pursuing diverse and collaborative strategies to grow their

presence and address market challenges, leveraging shared resources, financial innovation, and community engagement.

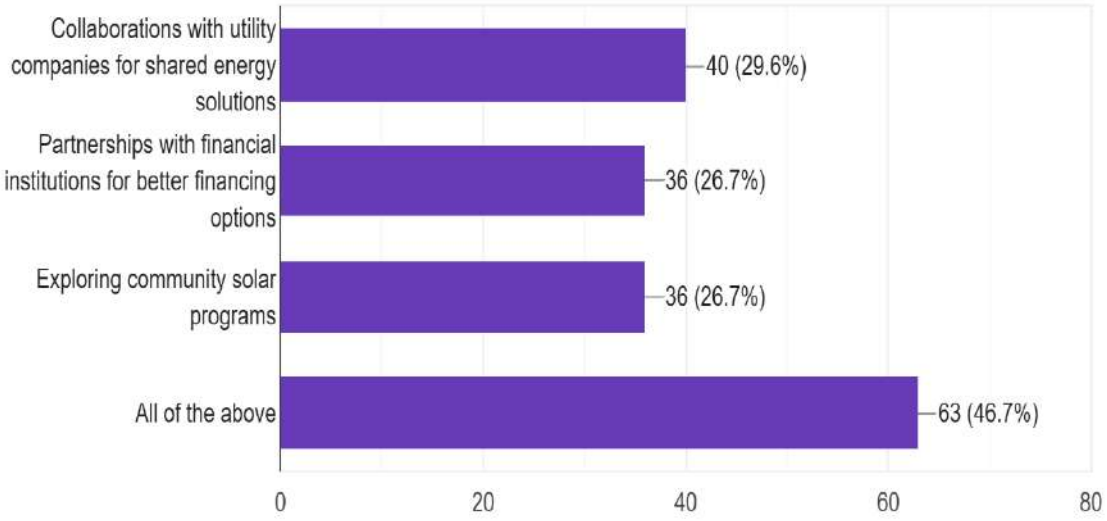

Figure 27 Exploring innovative business models and partnerships to expand market reach in industrial solar.

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Chapter 4

Policy Recommendations

Based on the extensive surveys of the solar companies, several systemic barriers and market trends were identified that hinder or enable the adoption of solar energy, particularly in the industrial sector. This chapter outlines the core challenges solar companies face, summarizes their collective expectations from the government, presents our independent policy recommendations, and highlights upcoming government interventions such as taxation and regulatory changes. These insights aim to strengthen the policy ecosystem to support wider adoption and sustainable growth in industrial solar energy.

1.11. Challenges Faced by Solar Companies: Policy Gaps and Market Barriers

The survey data identifies several critical challenges that solar companies repeatedly encounter:
a) High Upfront and System Costs: 80.1% of respondents cited high capital expenditure as the most significant barrier to industrial solar adoption. Despite long-term savings, the initial investment continues to deter many clients, especially in capital-intensive sectors.
b) Regulatory and Policy Delays: Nearly 60% of companies reported delays in obtaining permits and clearances, often due to inconsistent or opaque regulatory processes. In addition, 58.9% cited the lack of a clear, standardized regulatory framework as a major obstacle.
c) Inconsistent Taxation and Net Metering Policies: Inconsistent or rapidly shifting tax policies (48.9%) and net metering regulations (48.2%) create uncertainty, discouraging long-term investment and planning by industrial clients and solution providers alike.
d) Low Financial Service Penetration: Only 30.7% of companies currently offer financing or leasing services, showing a significant gap in making solar solutions financially accessible to industrial clients.
e) Limited Adoption in Agricultural and Niche Industrial Sectors: Despite potential demand, the agriculture sector is underserved. Only 0.7% of companies reported installations over 50 MW, and 8.1% reported no installations at all in agriculture.
f) Supply Chain and Installation Space Issues: 51.8% of respondents face challenges with the availability and logistics of solar components, while 49.6% reported space constraints, particularly for industrial rooftops and large equipment installations.

1.12. What Solar Companies Expect from the Government

Respondents shared clear, actionable policy suggestions that would foster faster and more widespread industrial solar adoption:

- *Increased Tax Incentives (72.1%):* To reduce the financial burden of upfront investment, solar companies overwhelmingly recommend robust tax incentives, including accelerated depreciation, GST exemptions, and capital subsidies for industrial solar installations.
- *Stable and Transparent Net Metering Policies (64.3%):* Industrial clients seek consistent net metering policies that ensure long-term energy credit mechanisms and predictable returns, aligned with state electricity board frameworks.

- *Faster Permit Approvals (33.6%):* Simplifying and digitizing the permit approval process for industrial-scale installations is seen as critical to avoid project delays.
- *Grid Access Incentives (25.7%):* Encouragement of grid-tied systems through financial and technical support is recommended, especially for high-capacity users.
- *Promotion of Local Manufacturing (suggested by a few):* Although less emphasized, some respondents supported policies promoting local solar panel and battery manufacturing to reduce reliance on imports and cut costs.

1.13. What need to be done

Based on analysis and stakeholder feedback, we offer the following evidence-based policy recommendations to the government:

Introduce an Industrial Solar Capital Grant Program: We recommend the introduction of direct capital grants covering 15–25% of system costs for industries installing solar power above 500 kW capacity, to mitigate upfront investment hurdles.

Create a Unified Solar Policy Framework for Industrial Users: A central policy should standardize regulatory approvals, streamline timelines, and harmonize tax incentives across states, providing industrial clients and providers with predictable and business-friendly conditions.

Establish a Green Energy Financial Access Scheme (GEFAS): A government-backed financing scheme in collaboration with banks and NBFCs could help solar companies offer leasing and deferred payment options to their clients. Special provisions should be made for MSMEs and export-based industries.

Mandate Time-Bound Permit Approval via Single Window Clearance: We recommend a digital "single-window" system for solar installation permits, with automatic approvals if delays exceed predefined timelines, especially for large-scale industrial projects.

Encourage Solar in Agricultural and Underrepresented Sectors: Introduce targeted incentives or pilot programs for agricultural processing units, cold storage, and agro-industrial clusters. These sectors have high energy needs and would benefit significantly from subsidized solar adaption.

Support R&D in Storage and Integration Technologies: Public-private partnerships for R&D in energy storage (especially batteries) and grid integration should be prioritized, helping companies overcome cost and efficiency limitations.

1.14. Government stand

In response to the evolving needs of the industrial solar market, several government initiatives are either planned or under active consideration:

- *Revised GST Framework (2025–2026):* The Ministry of Finance is evaluating proposals to reduce GST on solar components from 12% to 5% for projects above 1 MW, easing financial pressure on large-scale deployments.
- *New Net Metering Policy (Draft Stage):* A national-level policy on net metering is under review by the Ministry of Power, aiming to bring uniformity across state-level DISCOMs and ensure credit carry-over periods up to 24 months.

- *PLI Scheme Phase 3 for Solar Panels and Batteries:* A Production-Linked Incentive (PLI) scheme for domestic manufacturing of N-Type panels and lithium-ion batteries is being developed, targeting import substitution and supply chain resilience.
- *Green Energy Corridor 2.0:* Under this initiative, targeted industrial zones will receive upgraded infrastructure for grid synchronization of solar and hybrid systems, particularly in power-intensive sectors like textiles and food processing.

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Chapter 5

Conclusions

This study set out to examine the dynamics of industrial solar adoption in Pakistan from the perspective of solution providers. Drawing on 140 completed surveys across seven major cities, secondary context on national energy trends, and a careful synthesis of company-level practices and challenges, several clear conclusions emerge about the current state of Pakistan's industrial solar market, its drivers, remaining obstacles, and the practical policy interventions most likely to accelerate a just and scalable transition.

1.15. Solar rush, driven by distributed adoption, is reshaping Pakistan's energy landscape

Pakistan's solar market has expanded quickly: distributed and rooftop systems dominate the capacity additions while utility-scale deployment is growing more slowly. By mid-2025, the sector's momentum is best characterized by:

Strong grassroots adoption (households, commercial, agricultural users) that pushed net-metering capacity and rooftop installations into the multi-GW range.

A solar industry composed mostly of young to mid-age firms (the bulk with 2–10 years' experience), supported by an emerging set of larger players able to deliver high-capacity projects.

This pattern implies that solar is already functioning as a decentralized reliability and cost-saving solution for many industrial and commercial users, even while the grid and policy frameworks catch up.

1.16. Financial returns and technical performance are primary adoption drivers

Surveyed companies consistently reported that industrial clients are motivated first and foremost by strong financial metrics ROI, operational savings, and benefits from net metering and secondarily by technical considerations such as panel efficiency and lifespan. In practice this means:

High-efficiency technologies (notably N-type panels) are preferred because they deliver better energy yield and shorter payback periods for industries with high demand profiles.

Net-metering arrangements and predictable financial modeling remain central to project bankability.

1.17. Upfront costs, regulatory uncertainty, and supply constraints remain the largest barriers

Despite clear demand and demonstrable benefits, three categories of barriers persist:

Cost barrier: Upfront capital requirement is the most cited deterrent (≈80% of respondents), with batteries and total system cost also important. This limits adoption among cash-constrained firms and MSMEs.

Policy and regulatory friction: Lack of a unified regulatory framework, shifting net-metering rules, and permit delays create uncertainty that discourages long-term industrial investment.

Operational and market constraints: Supply chain bottlenecks, installation space constraints, and uneven access to financing further slow some projects and concentrate activity in certain sectors (textiles, food & beverages) and geographies (Punjab, Sindh).

Industry is responding with diversified service models but financing products are under-offered: Most companies offer installation, maintenance, design and after-sales support; however, only about 30% provide financing or leasing solutions. This represents a missed opportunity:

Companies that can combine technical delivery with flexible financing stand to capture a larger share of latent demand, particularly among MSMEs and agricultural processors.

There is clear appetite among providers to develop partnerships (with utilities, financiers, and community programs) to broaden access and share risk.

1.18. Emerging technologies (storage, smart integration, advanced modules) are viewed as growth levers

Respondents identified a portfolio of technological trends—advanced high-efficiency modules, batteries and energy storage, and smart grid/IoT integration—that will shape the sector's future. The combined deployment of these technologies can:

Improve utilization and reliability of solar in industrial settings (addressing concerns about intermittency and suitability for continuous processes).

Raise the value proposition by enabling time-shifted consumption, peak shaving, and better grid services.

1.19. Targeted policy interventions would unlock scale, equity, and resilience

The policy recommendations that surfaced in the survey and from our analysis point to concrete, high-leverage reforms:

Direct cost reductions: Time-bounded capital grants or accelerated depreciation for industrial systems above a threshold (e.g., 500 kW) would address the principal upfront barrier.

Stable, harmonized net-metering and tax frameworks: A unified national policy with predictable crediting, harmonized tax treatment, and clear interconnection rules will reduce investor risk and transaction costs.

Financing facilitation: A government-backed financial access scheme (GEFAS) operated with commercial banks and NBFCs would enable leasing and pay-as-you-save models that make solar affordable for MSMEs and agro-processors.

Single-window, time-bound permitting: Digitized approvals with automatic escalations would cut project lead times and lower soft costs.

R&D and local manufacturing support: PLI-style incentives and public-private R&D programs for storage and local module/battery manufacturing would strengthen supply resilience and reduce dependency on imports.

1.20. Equity and distributional considerations must be central to scaling solar adoption

The current boom benefits those with capital, grid access, and technical know-how, risking distributional gaps (e.g., smallholder farmers, informal sector units, and remote agro-processors). Policies should explicitly:

Prioritize MSMEs and agricultural processors through concessional financing, dedicated pilot programs, and targeted grants.

Encourage community and shared-asset models (community solar, industrial cluster solar) to spread benefits where rooftop or site constraints exist.

Practical next steps for stakeholders

Government: Codify a unified industrial solar policy, enact financial incentives, operationalize single-window permitting, and launch targeted industrial pilot programs in high-demand sectors.

Financial institutions: Build tailored credit products and leasing frameworks for solar + storage, and collaborate on guarantee mechanisms to de-risk lending.

Solar companies: Expand financing partnerships, document and publish detailed case studies (many already do), and invest in integrated offerings (panels + storage + O&M) to improve customer stickiness.

Industrial consumers: Conduct energy audits, evaluate high-efficiency N-type module options, and consider phased deployment with storage to improve reliability and economics.

1.21. Limitations and directions for future research

While the mixed-methods survey provides a robust snapshot across seven key cities, the study's purposive sampling and concentration on urban industrial centers limit its representativeness for small, remote, or informal rural firms. Future work should:

Expand sampling to underrepresented provinces and agricultural districts.

Track longitudinal outcomes of projects (actual versus modeled ROI) and the real-world performance of N-type modules and storage in Pakistan's climate.

Evaluate the social impact (jobs, energy access, and local supply chain development) of scaling domestic manufacturing for PV and batteries.

1.22. Final synthesis

Pakistan stands at a pivotal moment, where solar energy particularly distributed rooftop and industrial systems is already delivering tangible financial and reliability benefits, and technology improvements (high-efficiency modules, storage, smart integration) make deeper penetration feasible. Yet, to translate the present momentum into a resilient, equitable, and long-term industrial solar transition, coordinated action is required across finance, regulation, and industrial policy. If the government implements predictable net-metering, reduces upfront burdens through targeted incentives and financing programs, and streamlines approvals, Pakistan can accelerate industrial solar deployment, reduce reliance on costly fossil imports, improve grid resilience, and realize meaningful emissions reductions all while creating opportunities for domestic industry and improving energy access for traditionally underserved sectors.

These combined industry signals and policy levers present a clear roadmap: the private sector is ready to scale, technology is maturing, and well-designed government interventions would catalyze broader, faster, and fairer adoption of industrial solar across Pakistan.

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