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Enhancing Renewable Energy Integration in Developing Countries: A Policy-Oriented Analysis of Net Metering in Pakistan Amid Economic Challenges

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Abstract: Net metering (NM) is among the potent regulatory tools used globally for supporting distributed generation and renewable energy sources. This paper examines the trajectory of NM in a developing country such as Pakistan, analyzing the impact of regulatory changes, confidence-building strategies, hindering factors, and technical/financial issues. The three-stage methodology involves three components, namely techno-economic analysis, stakeholder engagement surveys, and impact analysis of financing mechanisms. This study emphasizes the importance of clear regulatory and financial frameworks, grid upgrades, and public–private partnerships for technology distribution in the context of a developing country with weak grid utilities and an import–export energy ratio. It also explores the role of financial incentives, such as tax breaks and subsidies, to encourage investment in NM systems from the perspective of lucrative rates, impact on paybacks, and return on investments, and proposes concrete solutions to enhance financial inclusion for ambitious renewable energy goals. Until April 2023, over 56,000 NM/distributed generation facilities were commissioned, with an installed capacity of 950 MW. By May 2024, the number of NM consumers reached ~100,000, with a 1950 MW capacity, nearly doubling. However, the import and export ratio of IESCO changed most, with 61% exports and 39% imports, directly impacting the revenue stream. A total of 60% of banks have adopted actions linked with green banking criteria, aiming to limit their environmental impact. The change in tariff will result in reduced ROI for NM consumers to 20%, and increase the payback period from less than 4 years to 13 years. Government subsidies, tax breaks, and green financing frameworks are proposed to encourage investment, but have been abruptly halted, and were previously at a 6% interest rate. This research aims to provide insights into effective market evaluation methodologies for NM programs and offer policy recommendations to strengthen legislative and institutional frameworks governing NM.

Keywords: distributed generation; energy policy; green financing mechanisms; net metering; renewable energy; regulatory framework

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1. Introduction

Net metering (NM), a crucial approach in incorporating renewable energy sources (RESs), allows users to both consume and generate electricity from the grid [1]. The NM strategy has garnered global attention, especially in developing nations grappling with economic challenges. Motivated by the necessity for sustainable energy solutions to bolster economic stability and address environmental concerns, these countries seek to adopt NM for long-term benefits. In the broader context of global NM initiatives, developed nations like Germany, the US, and Australia have taken the lead in establishing regulations. Their efforts have resulted in the successful implementation of distributed renewable energy systems, contributing to carbon emission reduction and stimulating economic growth through job creation and technological advancements in the renewable energy sector [2]. However, developing countries encounter distinct challenges in RES integration, impeding enthusiastic NM adoption due to constraints such as limited resources, inadequate grid infrastructure, and regulatory complexities [3].

Amid an economic downturn, Pakistan's NM landscape provides an interesting case study. The country is dealing with energy scarcity as its population grows, emphasizing the essential need to exploit renewable energy supplies. The process of implementing NM in Pakistan began in 2015 with the passage of the Distributed Generation and NM Regulations [4]. The National Electric Power Regulatory Authority (NEPRA) established the regulatory framework for NM, which allows residential, commercial, industrial, and agricultural sectors to generate power while receiving credits for excess energy pumped into the grid [5]. NM is consistent with the country's goal to develop inexpensive and environmentally sustainable renewable energy, which contributes to SDGs 7, 9, 11, and 13.

A comprehensive literature review of reported works has offered an in-depth analysis of the multifaceted difficulties and opportunities associated with NM systems, spanning technological, economic, social, and regulatory elements [6–9]. These studies, taken together, form a solid basis. Examining policy considerations, Blumschein et al. [10] uncovered significant legislative disparities across US states, impacting consumer participation and renewable energy sources (RESs) integration. Wang et al. [11] conducted a comprehensive cost–benefit analysis, revealing the influence of tariff structures, system capacity, and consumer behavior on NM outcomes. Azimoh et al. [12] emphasized legislative constraints and low consumer awareness as obstacles to NM's potential in developing nations. N. Patel et al. [13] found that well-structured NM frameworks enhance solar photovoltaic (PV) system deployment in India, contributing to RES targets. Investigating NM programs, J. Park et al. [14] stressed the need for policy stability in California to foster renewable energy adoption. M. Smith et al. [15] identified administrative barriers and insufficient incentives as major impediments. S. Lee et al. [16] examined the econometric impact of NM in South Korea, highlighting the importance of incentive-based tariff design. S. Kim et al. [17] emphasized regulatory frameworks balancing utility and customer interests. Notably, policies applicable to developed countries may not align with developing nations with weak grids and increasing NM penetrations.

Addressing technical challenges, Jacobson et al. [18] highlighted voltage regulation and grid stability issues, emphasizing improved grid management. Rahman et al. [19] explored energy storage integration with NM, showcasing its potential for grid stability. Gupta et al. [20] evaluated grid integration challenges, stressing advanced technologies for seamless operation. Martinez et al. [21] explored NM's role in improving grid resilience during adverse weather. Inadequate planning, public knowledge gaps, and environmental benefits were discussed [22–27]. Evaluating economic aspects, stakeholders' decisions to invest in PV and NM technology are influenced by economic variables [28–35]. The capital-intensive nature, lower tariff rates, high initial costs, maintenance expenses, and payback periods are identified as key economic considerations [36,37].

NM has demonstrated positive outcomes by decreasing consumer costs, improving voltage stability, and reducing transmission and distribution losses. Despite these benefits, challenges such as transformer overloading, potential financial impacts on distribution companies (DISCOs), concerns regarding NM payments, and generation losses during load shedding require in-depth investigation. Addressing these economic issues is crucial to consider stakeholders' perspectives, particularly in the context of developing nations like Pakistan dealing with financial crises and the imperative for grid reinforcement [38,39].

The commissioning of nearly 100,000 NM units with a cumulative installed capacity of 1950 MW by 21 May 2023, generating on average 3800 MWh daily, demonstrates Pakistan's quick adoption of NM. An ambitious expansion plan, stated in the Indicative Generation Capacity Expansion Plan (IGCEP) 2022–2031, promises to add an extra 3420 MW of NM capacity by 2031, demonstrating a strong commitment to green energy integration. However, the road to a successful NM regime is not without obstacles [6,36–39]. NEPRA's recent proposed revisions to the NM Regulations have raised anxiety among stakeholders, notably DGs, because prospective changes in reduced energy purchase costs could impair the feasibility of NM projects. NEPRA proposed amendments to the NM Regulations, which caused consternation among the key stakeholders. The DG stakeholders have expressed worry that these modifications may undermine efforts to reach the IGCEP targets [7,40,41]. The proposed adjustments are expected to lower the incentives for suppliers of RE-DG-based electricity to DISCOs participating in the NM program. The price payable to DGs will be the National Average Energy Purchase Price (NAEPP) rather than the National Average Power Purchase Price (NAPPP). The proposed NAEPP is roughly 9 PKR/kWh, while the present NAPPP is around 19.32 PKR/kWh [8,9,42,43]. This can place DG stakeholders in a disadvantage position. However, such a move by the regulator can undermine consumer trust and hinder the growth of the NM system in a developing nation like Pakistan during an economic downturn [44–46].

Against this backdrop, the goal of this research paper is to thoroughly examine the NM situation in Pakistan. It intends to investigate the operational complexities, working conditions, financial incentives, legislative frameworks, and issues related to NM. Furthermore, the study will dive into the financial landscape, analyzing the funding sources and incentive programs supplied by domestic banks, the State Bank of Pakistan (SBP), private sector firms, and relevant organizations. The main contributions of this study include the following:

- To provide the current state of NM in Pakistan from a techno-economic perspective, and public perceptions of net-metered connections.
- To identify the policy framework deficiencies, issues encountered by users and stakeholders, and bottlenecks impeding the growth of net-metered connections.
- To determine the financial sources and incentive programs for NM supplied by domestic banks, SBP, the private sector, and other organizations.
- To identify the issues, roadblocks, and bottlenecks that restrict citizens from obtaining and using financial services in developing countries like Pakistan.
- To indicate financing issues in getting concessionary loans from bank financing institutes.
- NM program evaluation across the complete supply chain, from solar PV system installation through connection tracking and potential future financial rewards.
- Policy suggestions to make the techno-economic and administrative framework for NM more people-centric.
- A future road map for boosting the development of net-metered connections should be considered, and policy recommendations based on economically and technologically sound objectives should be proposed.
- To examine the technical and financial difficulties and challenges faced by stakeholders in installing NM technology, several solutions will be proposed.
- To incorporate stakeholders' perspectives in future NM regimes.
- To offer a composite methodology along with a stakeholders' survey supported by quantitative analysis.
- This study will serve as a guideline for developing countries to address the limitations in their respective NM regime.

The paper is structured as follows: Besides presenting the literature review, Section 2 outlines the NM system in Pakistan. Section 3 details the three-stage methodology. Section 4 presents result and discussions, encompassing techno-economic in-depth analysis, stakeholder engagement, and financial mechanisms. The key challenges in availing concessionary financing are mentioned in Section 5. This paper concludes in Section 6 with policy implications.

2. Data of Net-Metering Systems in Pakistan

Implemented in 2015 through NM Regulations in alignment with Pakistan's 2019 alternative and renewable energy policy, the NM system primarily targets solar PV and wind technology. Consumers can install distributed generation facilities up to 1.5 times their sanctioned load, capped at 1 MW. Presently, eligibility is limited to three-phase consumers at 400 V or 11 kV, with plans underway for single-phase connections. Despite a 15% loading capacity constraint on distribution transformers, grid operations face challenges such as frequent tripping and transformer damage. Concerns regarding inverter quality and adherence to international performance standards persist. DISCOs are actively developing advanced control centers to manage the increasing penetration of renewable energy (RE) in the market.

Table 1 shows NM connections across 11 DISCOs and other entities like Bahria Town Rawalpindi and DHA Lahore. From 2016 to 2022, NM capacity and connections increased by approximately 141% and 66% respectively, except for a dip in 2022. Lahore Electric Supply Company (ESCO) or LESCO, Multan Electric Supply Company (MEPCO), and K-Electric (KE) lead in NM capacity, while Islamabad ESCO (IESCO), Lahore ESCO (LESCO), and K-Electric excel in NM connections. The trends of NM in terms of consumer classes are categorized as residential/domestic (R/D), commercial (C), industrial (I), agriculture (A), and others/general services (O/G). R/D consumers dominate, especially in LESCO (60.34%), followed by IESCO (18.31%). Hyderabad ESCO (HESCO) and Tribal ESCO (TESCO) have the fewest NM connections. It is shown in Figure 1 that among public DISCOs, IESCO, LESCO, and Peshawar ESCO (PESCO) have high R/D connections, while Sukkur Electric Power Company (SEPCO) has the least. SEPCO leads in commercial and industrial connections, while Multan Electric Power Company (MEPCO) leads in agriculture.

Table 1. Connections and (capacity) distribution across Pakistan (2015–2022) (Source SOI, NEPRA) [36,37].

DISCOs	2015–2016	2016–2017	2017–2018	2018–2019	2019–2020	2020–2021	2021–2022
PESCO	-	-	37.56 **(2)**	96.6 **(10)**	3200.84 **(131)**	6064 **(525)**	12,510 **(392)**
TESCO	-	-	-	-	-	298.08 **(1)**	175.23 **(1)**
IESCO	1020 **(2)**	1008.96 **(49)**	1732.81 **(114)**	3849.07 **(377)**	9990 **(863)**	24,439 **(1976)**	22,860 **(1507)**
GEPCO	-	11 **(3)**	1190.37 **(31)**	908.64 **(56)**	4720 **(134)**	11,138 **(433)**	23,290 **(513)**
LESCO	-	468.2 **(36)**	3204.43 **(142)**	7154.44 **(348)**	14,980 **(886)**	41,126 **(2170)**	62,390 **(1790)**
FESCO	-	305 **(2)**	217.6 **(13)**	258.17 **(24)**	3960 **(152)**	14,879 **(564)**	26,620 **(558)**
MEPCO	-	470.57 **(10)**	251.96 **(7)**	1129.94 **(47)**	4300 **(166)**	17,928 **(876)**	46,980 **(1018)**
HESCO	-	-		10.08 **(1)**	220 **(6)**	951 **(11)**	4130 **(64)**
SEPCO	-	-		964.91 **(1)**	469 **(5)**	136 **(7)**	2290 **(13)**
QESCO	-	-		6.18 **(1)**	20 **(1)**	326 **(4)**	220 **(9)**
K-Electric	-	-	288.4 **(28)**	4270.21 **(253)**	12,240 **(730)**	23,885 **(1357)**	41,450 **(1078)**
Others	-	52.95 **(6)**	84.79 **(13)**	501.02 **(49)**	2770 **(260)**	5009 **(494)**	540 **(89)**
Total	1020 **(2)**	2316.68 **(106)**	7007.91 **(350)**	19,149.24 **(1167)**	56,869.84 **(3334)**	146,179.1 **(8418)**	243,455.2 **(7032)**

Figure 2a–f illustrates the distribution of consumer classes across DISCOs. IESCO boasts the highest percentage (92.04%) of residential and domestic (R/D) connections, closely followed by LESCO (91.19%) and PESCO (88.59%). SEPCO exhibits the lowest percentage of R/D connections (37.03%), with QESCO displaying the smallest difference between export and net import. Notably, SEPCO leads in commercial consumers (18.52%), while MEPCO (14.67%) and HESCO (14.29%) follow suit, and LESCO has the fewest commercial consumers (4.38%). In the industrial consumer category, SEPCO secures the highest percentage (19.63%), with GEPCO demonstrating the largest difference between export and net import. MEPCO claims the highest percentage (1.3%) in the agriculture prosumer class, featuring the highest difference between export and net import in this category. Quetta ESCO (QESCO) exhibits the highest difference between export and net

import for other and general services consumer connections. Lastly, in the national context, LESCO leads in consumer connections (60.343%), with IESCO ranking second (18.31%), albeit with a less favorable export and net import balance. Further analysis delves into IESCO's potential impact across all DISCOs.

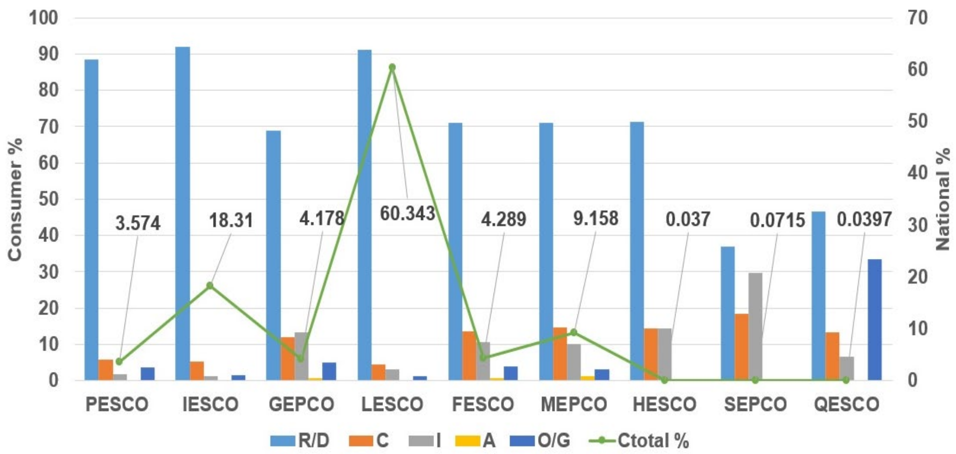
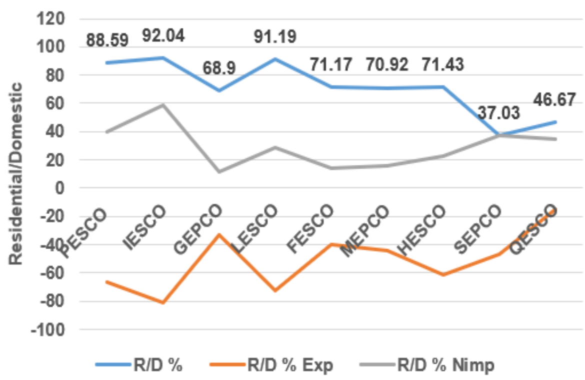
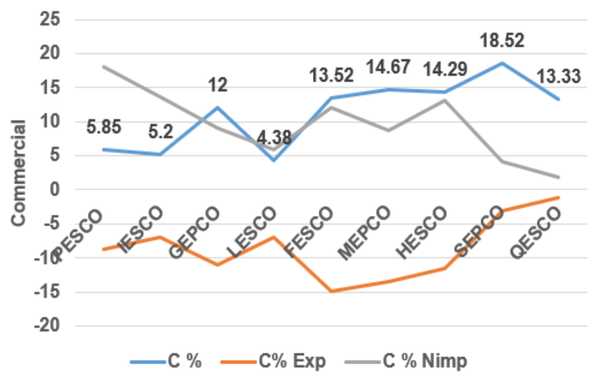


Figure 1. NM consumers' % and national % share in Pakistan until 2021–2022 [36–38].



(**a**)



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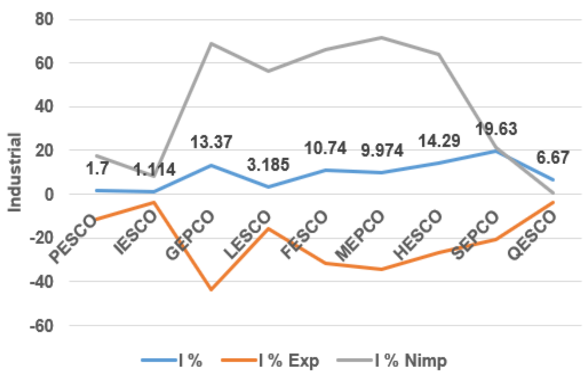

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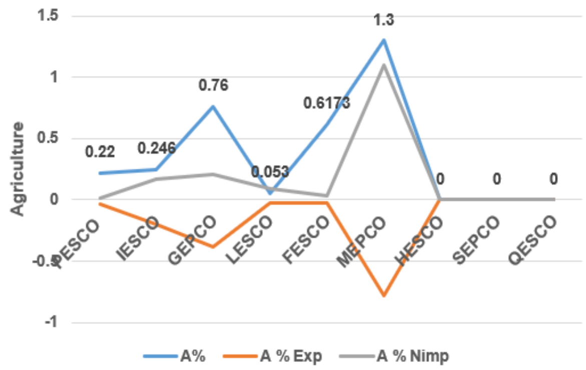
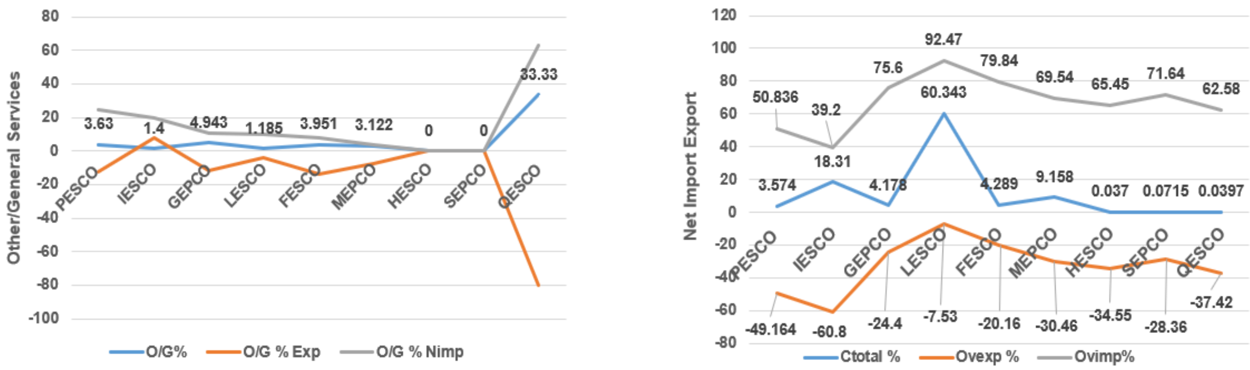


(**d**)

Figure 2. *Cont.*



(**e**) (**f**)

Figure 2. (**a**–**f**): NM consumers' distribution and net import export balance of all public utilities per classification.

NEPRA has categorized NM consumers into three groups based on the size of their PV systems. The first category includes low-capacity consumers with systems under 11 kW, deemed the most cost-effective option with storage. The medium category encompasses systems ranging from 11 kW to 25 kW, falling under the DISCO's jurisdiction for NM connections without necessitating a license from NEPRA for systems up to 25 kW. High-capacity consumers, with systems exceeding 25 kW, require a NEPRA license, as per the current status in IESCO. Table 2 details the distribution of NM systems in these classifications from 2015–2016 to January 2023, providing yearly percentage distributions. In IESCO, there has been a discernible decline in low-capacity connections and an increase in medium-capacity connections since 2019. Notably, high-capacity connections have seen a significant rise, impacting IESCO's export and net import balance. Initially set at three years, the license limit was extended to seven years in 2018. IESCO achieved peak connections and capacity addition in 2020–2021, with 1976 connections and an approximate addition of 24.439 MW.

Table 2. Connections distribution across various classification of prosumers in IESCO [38].

Year	<11 KW Low	<25 KW Medium	25 KW > High	Total	Low %	Medium %	High %
2016	10	4	4	18	55.6	22.2	22.2
2017	62	11	6	79	78.5	14	7.5
2018	127	54	10	191	66.5	28.3	5.2
2019	558	104	23	685	81.45	15.2	3.36
2020	1022	223	47	1292	79.1	17.3	3.6
2021	1915	596	103	2614	73.2	22.8	4
2022	121	98	118	339	35.7	28.9	34.8
2023 *	1	7	11	19	5.26	36.84	57.9
Total	**3816**	**1097**	**322**	**5237**	**72.87**	**21**	**6.15**

* Data until 31 January 2023.

Figure 3a–f elucidate the trajectory of NM connections in IESCO across consumer classes. Notably, low-capacity connections have seen a decline since 2019, whereas medium-capacity connections have witnessed a slight increase, and high-capacity connections have shown a significant surge. Despite constituting a smaller proportion in the system, high-capacity connections have made a substantial contribution to overall capacity, with their trend steadily rising since 2021–2022. Conversely, low-level connections, despite their larger numerical presence, have a comparatively smaller impact on both IESCO's exports and net import balance. Additional details on NM connections in Pakistan across 11 DISCOs can be found in Table A1 and Figure A1 in the Appendices A and B. For numerical verification, please refer to Table A1 (capacity) and Table A2 (connections) in Appendix A.

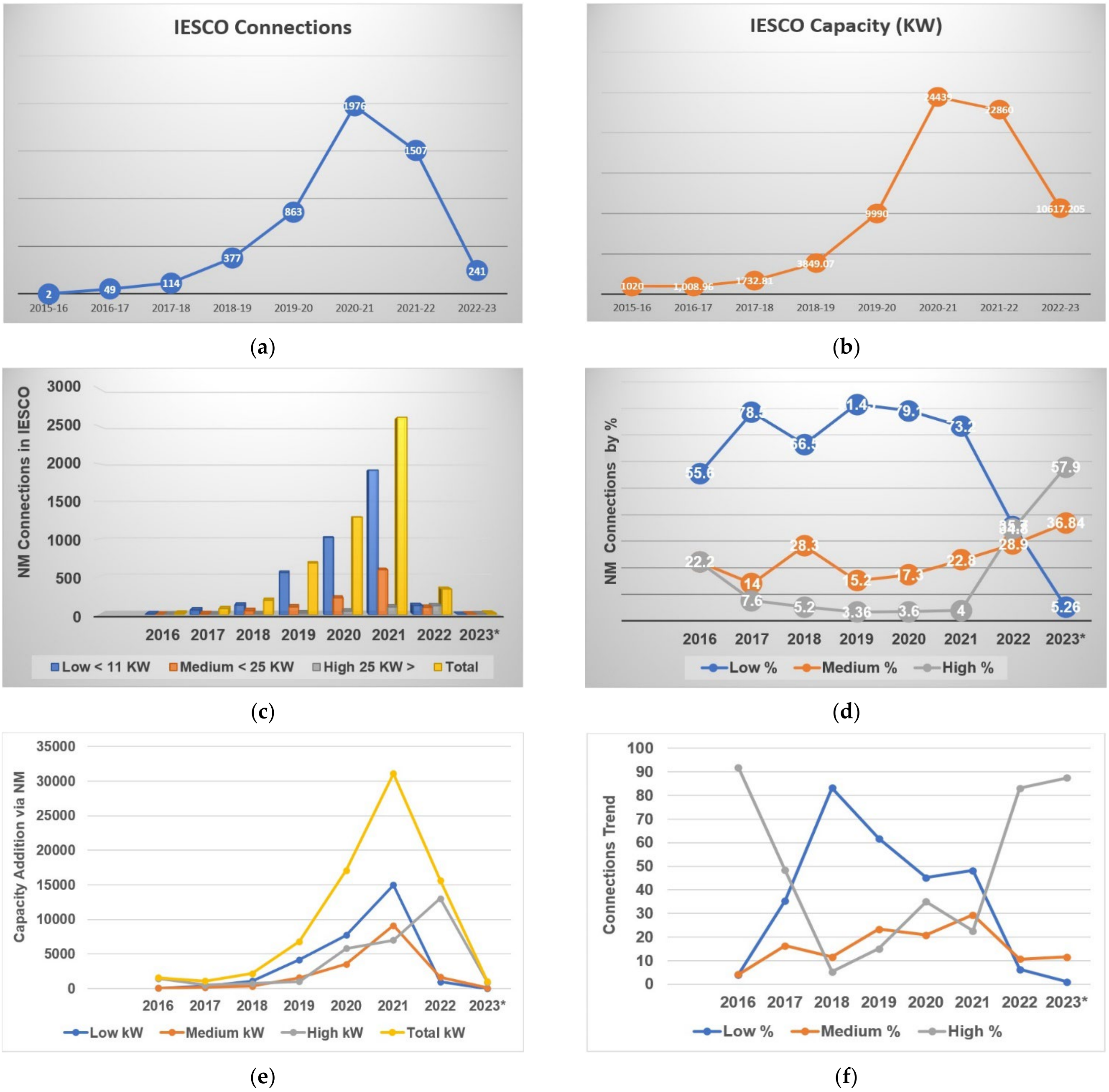


Figure 3. (**a**–**f**): NM consumers' distribution trend in IESCO per system size-based classification. (Where * is for alternate scenario at lower tariff in year 2023.)

3. Methodology

The research methodology employed in this study endeavors to tackle fundamental issues surrounding NM adoption and its implications in Pakistan. This approach integrates a multi-dimensional analysis, encompassing an overarching rationale, techno-economic impact assessment, stakeholder engagement, and financial mechanisms. Illustrated in Figure 4, the study's methodology is grounded in a conceptual framework that underscores the significance of considering the broader context and the current state of NM in Pakistan. This strategic approach serves as a starting point for addressing pertinent concerns identified by stakeholders, ensuring a comprehensive examination through the incorporation of diverse perspectives. The methodological framework is segmented into three distinct contingents, each contributing to a holistic understanding of the subject.

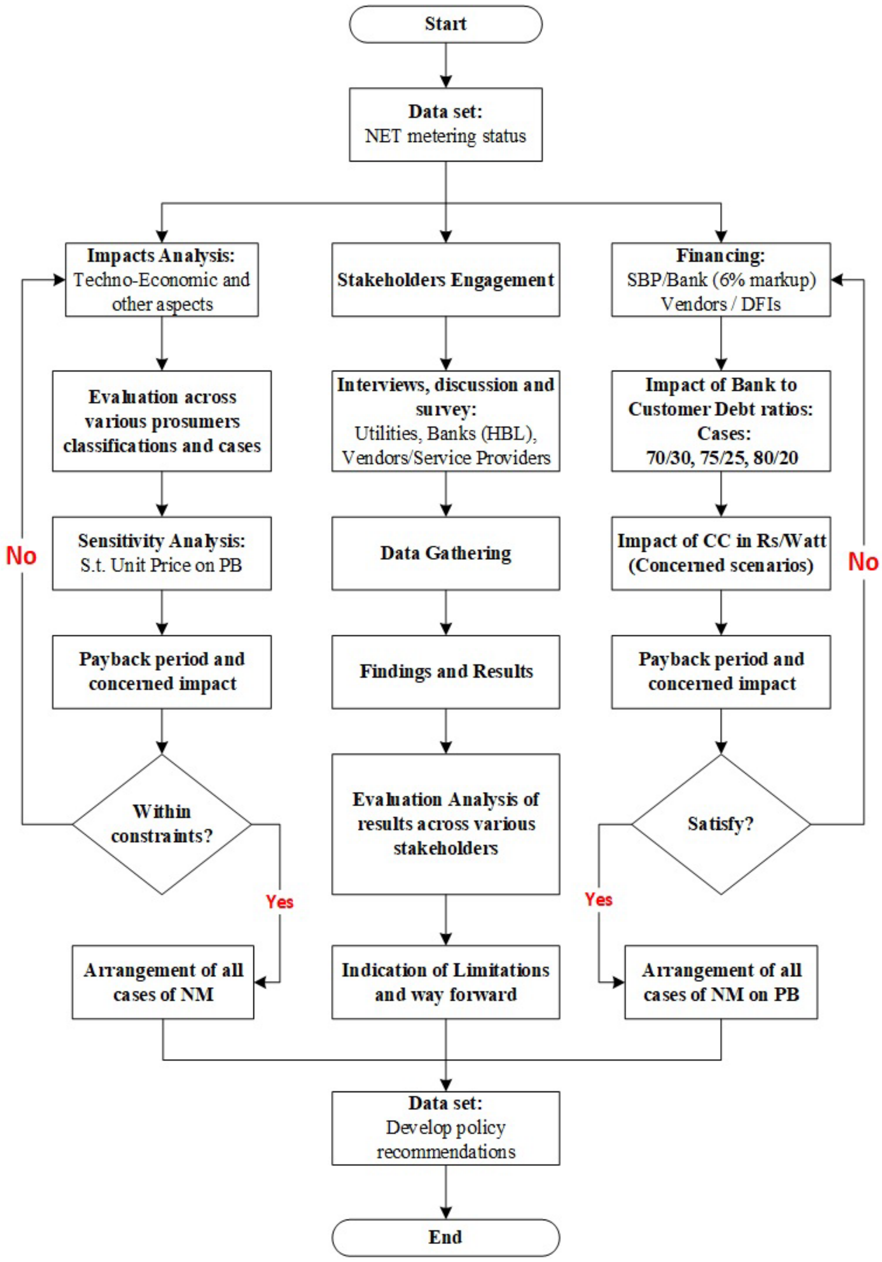


Figure 4. Flowchart of the methodology in this study.

The outcomes of this study's methodology yielded a thorough analysis covering various facets of NM installations. By integrating techno-economic assessments, stakeholder perspectives, and finance studies, it ensured a well-rounded comprehension of the subject matter. The methodology strived to offer quantitative insights supported by numerical data, facilitating the formulation of policy recommendations aimed at promoting net-metered connections within the banking industry.

3.1. Methodology Contingent-1: Techno-Economic Analysis

This comprises an in-depth effect study across multiple performance measures of Pakistan's NM status. This research uses a systematic assessment approach to analyze the techno-economic effects of extending payback periods. The analysis assessment of NM's impact on different capacity holders offers insight into the potential benefits and drawbacks of long payback periods.

3.2. Methodology Contingent-2: Stakeholder Engagement

This involves a hybrid methodology that combines online surveys and concentrated group talks. This method promotes a thorough awareness of stakeholder viewpoints, including their limitations and concerns. This component contributes to the formulation of an executable on-the-ground roadmap by capturing a diverse range of opinions, addressing identified limitations, and aligning stakeholder interests with NM implementation.

3.3. Methodology Contingent-3: Financing Mechanisms and Impact Analysis

This examines financing mechanisms and their impact on repayment scenarios in the current economic environment. These contingents use quantitative analysis to evaluate the viability and ramifications of various financing strategies. This element aids in the development of appropriate policy recommendations by explaining the financial issues connected with NM installation.

The methodology presented, encapsulating all three contingents, provides a solid platform for analyzing and resolving the issues and possibilities related to optimized NM adoption in Pakistan. This study strives to contribute to the promotion of policy suggestions that support the broad use of net-metered connections, hence facilitating sustainable energy practices and socioeconomic growth, through a comprehensive and multi-dimensional approach.

4. Results and Discussions

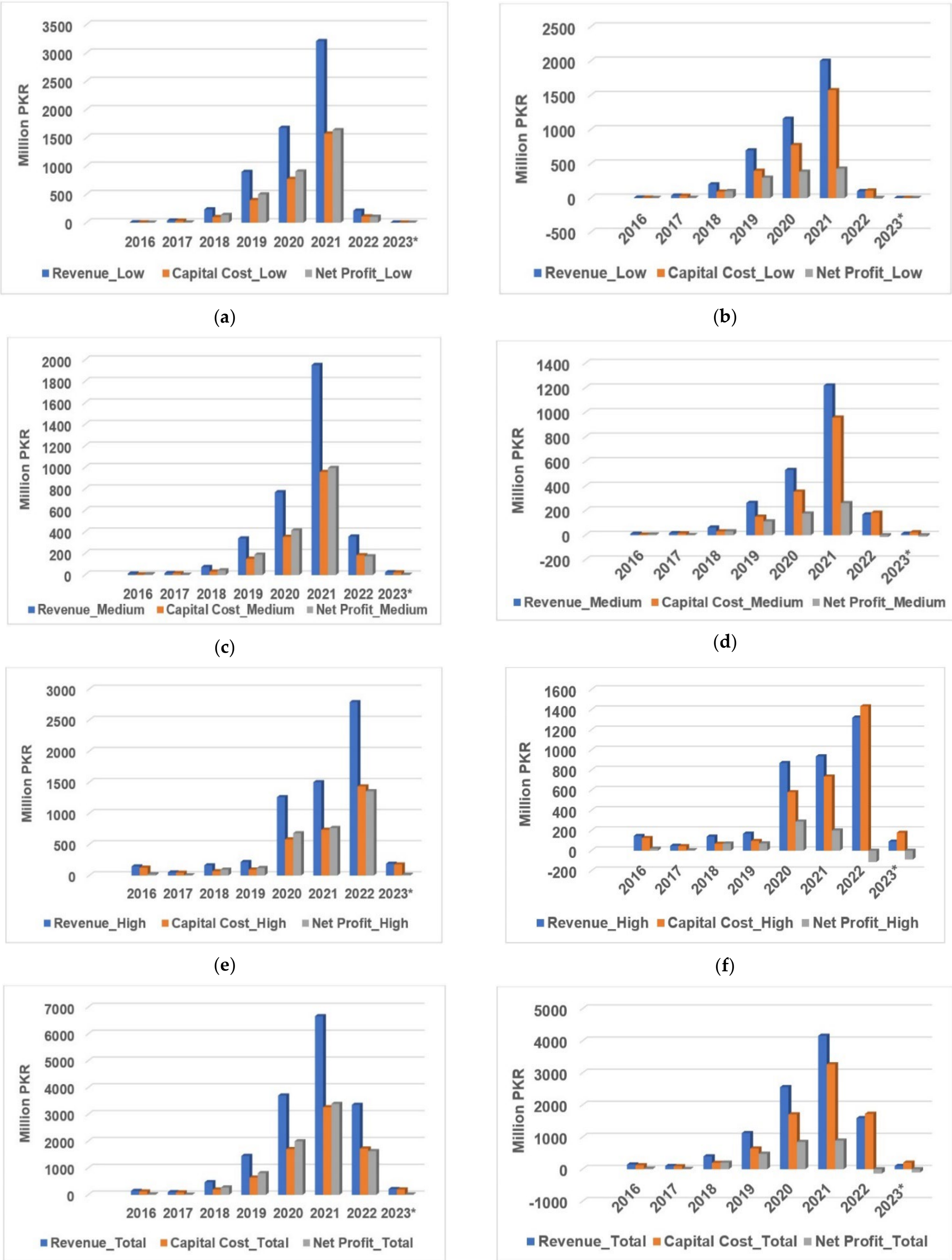
4.1. Analysis of Methodology Contingent-1: In-Depth Techno-Economic Analysis

The in-depth analysis encompasses critical parameters and assumptions, incorporating 328 sunlit days and 37 cloudy days in the IESCO region, resulting in an average daily solar exposure of 4.5 h. Considered factors include a 10% derating in PV system capacity, a 10% soiling factor, and a 0.5% annual efficiency reduction. The study assesses annual connections with corresponding capacities and system categorizations, along with the generated power over the initial 3-year license period and subsequent 7-year period. Revenue projections rely on the NAPPP of approximately 19 PKR/kWh and the NAEPP of about 9 PKR/kWh, normalized from January 2022 onwards. Capital costs, ranging from 200 to 220 PKR/Watt, are considered, with economic analyses employing varying debt-equity ratios (70/30, 75/25, 80/20) and elucidating diverse payback scenarios. Additional assessments include standard deviation for confidence levels, CO_2 emission reductions, alignment with SDGs, and an examination of the current status of green financing.

4.1.1. Sensitivity Analysis across Consumer Categories

The analysis explores three consumer categories (low, medium, and high) based on capacity from 2016 to 2023. Revenues are calculated using unit pricing of NAPPP at 19 PKR/kWh and NAEPP at 9 PKR/kWh (normalized for new connections from January 2022 to 2029). Capital costs range from 80 to 110 PKR/Watt (2016–2022) and 200 PKR/Watt (2023), reflecting economic conditions. Net profit is obtained by deducting capital cost from revenue. In Figure 5a, cumulative revenue peaks at PKR 3209.324 million in 2021, with a corresponding capital cost of PKR 1574.055 million, resulting in a net profit of around PKR 1635.27 million.

Figure 5b for NAEPP shows reduced revenue, higher capital cost, and diminished net profit, which even turned negative in 2021. Comparative analysis focuses on NAPPP for 2022 and 2023 Figure 5a and NAEPP for 2022_9 and 2023_9, as shown in Figure 5b. High capital costs notably lead to a significant decrease in net profit for 2023. In Figure 5b for NAEPP, net profit turns negative for both analyzed years, a consequence of elevated capital costs. Key indicators for comparison include LCOE, ROI, and PBP. For 2022_9, LCOE is PKR 9.76, ROI is 27.8%, and PBP is 3.6 years. In 2023_9, LCOE is PKR 17.75, ROI is 15.29%, and PBP extends to 6.54 years, highlighting a substantial disparity between consecutive years attributed to the NAEPP effect. Similar trends appear in Figure 5c,d for medium-sized systems and Figure 5e,f for high-capacity consumers, especially evident in 2022 and 2023. Figure 5g,h confirm these patterns across cumulative system sizes.



(**a**) (**b**)

(**c**) (**d**)

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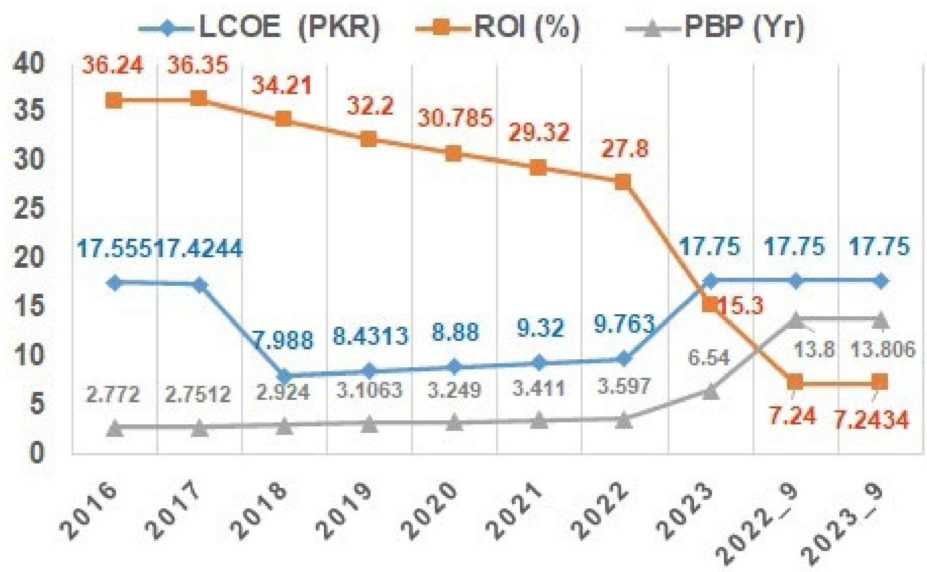
Figure 5. *Cont*.



(**i**)

Figure 5. Analysis across various sized systems with respective tariffs: (**a**) Low NAPPP ~19 PKR/kWh, (**b**) Low NAEPP 9 PKR/kWh; (**c**) Medium NAPPP 19 PKR/kWh, (**d**) Medium NAEPP ~9 PKR/kWh; (**e**) High NAPPP ~19 PKR/kWh, (**f**) High NAEPP ~9 PKR/kWh; (**g**) Comparative NAPPP ~19 PKR/kWh, (**h**) Comparative NAEPP ~9 PKR/kWh. (**i**) Analysis across LCOE (PKR), ROI (%), and PBP (years), for NAPPP ~19 PKR/kWh (horizon 2016–2023) and NAEPP ~9 PKR/kWh (horizon 2022_9 and 2023_9). (Where * is for alternate scenario at lower tariff in Year 2023).

Figure 5i analyzes LCOE (PKR), ROI (%), and PBP (years) for NAPPP (2016–2023) and NAEPP (2022_9 and 2023_9). The comparative curves of NAPPP and NAEPP reveal a flip in 2022 and 2023, potentially unsettling stakeholders. Comprehensive data on capacity and financial evaluation can be found in the tables in the Appendix A. The details regarding overall capacity, concerning financial evaluations from 2016 until 2023, can be found in Tables A3–A5, respectively, in Appendix A. The observed trends could undermine stakeholder confidence.

4.1.2. Sensitivity Analysis across Averaged Capacity

A comprehensive analysis covered various system sizes, as depicted in Figure 6a,b, presenting the assessment of average capacity and MWh from 2016 to 2023. High-capacity consumers (25 kW and above) notably emerged as primary contributors, influencing IESCO's import–export dynamics. Figure 6c,d delve into lower-sized systems, contrasting evaluations under NAPPP (19 PKR/kWh) and NAEPP (9 PKR/kWh) scenarios in Figure 6c,d. Viability is evident under NAPPP, while potential deficits for prosumers are indicated under NAEPP.

Figure 6e,f provide an in-depth analysis of medium-sized systems, with Figure 6e revealing viability under NAPPP and Figure 6f highlighting widening prosumer deficits under NAEPP. Moving to small-sized systems, Figure 6g indicates viability under NAPPP, while Figure 6h reveals pronounced prosumer deficits under NAEPP, particularly in the high-capacity class. Detailed averaged capacity and MWh evaluations from 2016 to 2023 are presented in Table A6. Financial evaluations, including revenue, capital cost, and net profit in million PKR, are provided in Table A7 under NAPPP and Table A8 under NAEPP in Appendix A.

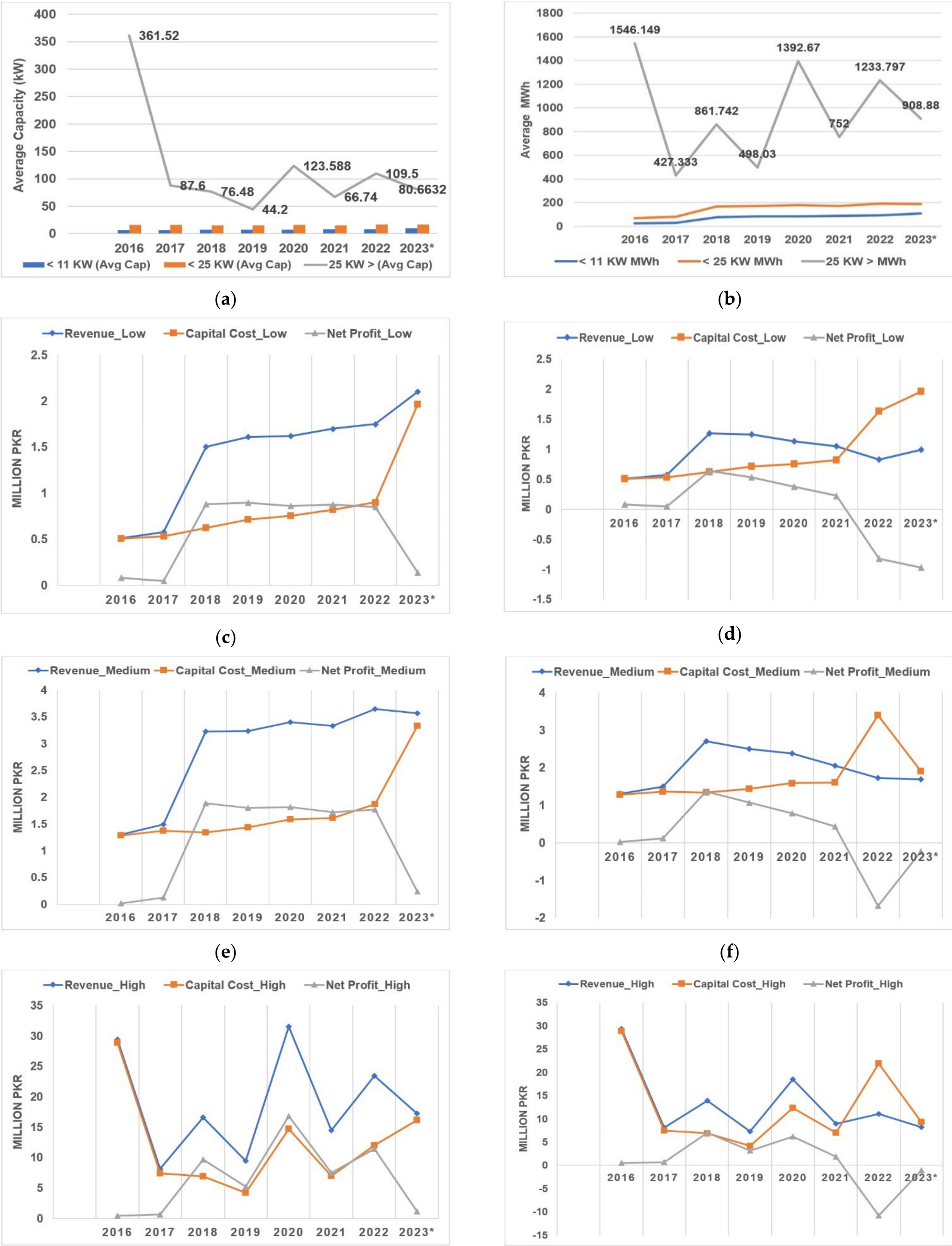


Figure 6. Analysis across various sized systems: (**a**) average capacity, (**b**) average MWh; (**c**) small-sized systems NAPPP ~19 PKR/kWh, (**d**) small-sized systems NAEPP ~9 PKR/kWh; (**e**) medium-sized systems NAPPP ~19 PKR/kWh, (**f**) medium-sized systems NAEPP ~9 PKR/kWh; (**g**) large-sized systems NAPPP ~19 PKR/kWh; (**h**) small-sized systems NAEPP ~9 PKR/kWh. (Where * is for alternate scenario at lower tariff in Year 2023).

Consumer confidence is analyzed in Figure 7a,b, addressing confidence in connection types and capacities, with the highest confidence levels observed in high-capacity connections during 2021–2022. Additionally, Figure 7c highlights the reduction in CO_2 emissions resulting from solar adoption, referencing a reduction rate of 6.9×10^{-4} metric tons of CO_2 per 1 kWh of solar energy [39]. The most substantial reduction occurred in 2021, totaling 241.934 thousand metric tons and contributing to a cumulative reduction of 583.42 thousand metric tons since the inception of the NM program in 2015–2016 until 31 January 2023.

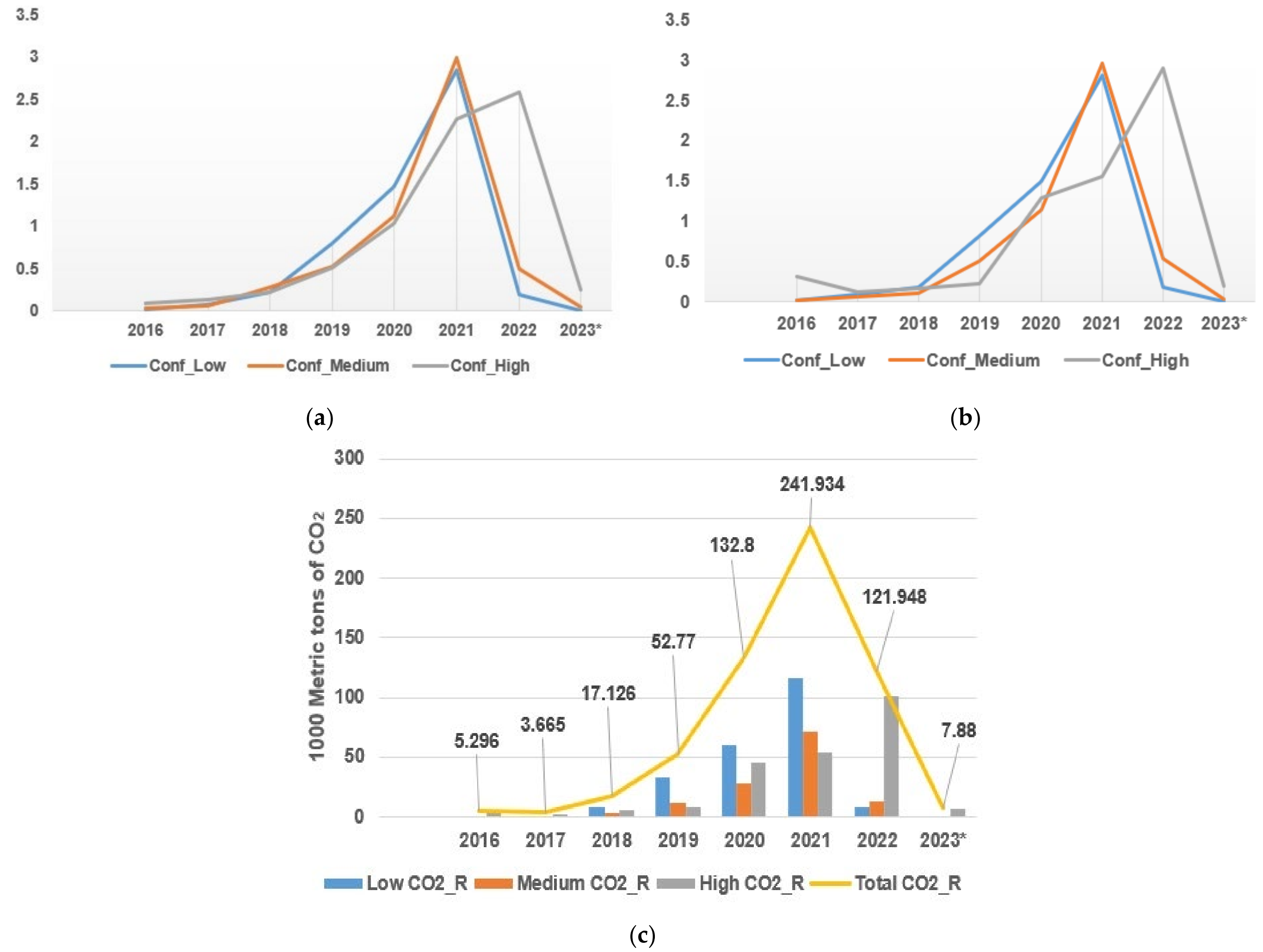


Figure 7. Analysis of consumer confidence: (**a**) confidence in type of connections, (**b**) confidence in connection capacity, (**c**) analysis of CO_2 emissions reduction via NM (where * is for alternate scenario at lower tariff in Year 2023).

4.2. Analysis of Methodology Contingent-2: Stakeholder Engagement

4.2.1. Survey across Utilities, Industries, Vendors, and Consumers

The survey was conducted using an online questionnaire, with the participants listed in Table 3.

Five categories—policy in Table 4, technical in Table 5, economic and financial in Table 6, energy security and governance in Table 7, and stakeholder engagement and capacity building in Table 8—were used to segment the poll. The options and questions for the interview are shown in Tables 4–8. On a score scale of 1–5, "1" stands for "Strongly Disagree/Unaware" and "5" stands for "Strongly Agree/Fully Aware".

Table 3. Stakeholders' classification in the conducted survey.

S#	Participants	Participants Classification	Responses
1	Utilities	GEPCO (2); PESCO (2); LESCO (4); IESCO (1); NTDC (2); NEPRA (1):	12
	Industry, Vendors, Installers	Mavetech (Pvt.) Limited (1); Crysto Solar Energy (Pvt.) Limited (1); Professional Energy Solutions (1); SunWatts Energy System (1)	4
	Consumers:	5.4 kW (Low); 12 kW (Medium); 25.6 kW (High)	3
2	Banks	SBP, HBL, Bank Alfalah	3
3	Focused Group Discussion	HBL	1

Table 4. Stakeholders' survey from policy perspective.

Sr. #	Questions (Policy Perspective)	Response
1	NM planning is important for energy policy.	4.54 (91%)
2	Achieve Energy Mix targets set by Government policies/regulatory authorities.	4.27 (85%)
3	NM improves scientific input to energy policy.	4.13 (83%)
4	Policy and planning institutions capacity do implement NM.	3.6 (72%)
5	Constraints importance within policy and planning institutions for NM.	4.3 (85.3%)
6	Poor training in policy analysis and formulation.	3.67 (73%)
7	Energy economics, planning, and policy.	4.8 (96%)
8	Policy Making and formulation.	5.0 (100%)
9	Involvement in policy activities.	4.47 (89%)
10	Rate potential stakeholders as future partners in the NM policy.	4.0 (80%)
11	Development of financial and policy formulation.	4.0 (80%)
12	Coordination with planning and policy institutions.	4.47 (89%)

Table 5. Stakeholders' survey from technical perspective.

Sr. #	Questions (Technical Perspective)	Response
1	Techno-economic-social infrastructure with NM can reduce energy shortfall.	4.0 (80%)
2	NM planning improves the diverse energy resources and technologies.	4.54 (91%)
3	NM contributes to electrical power grid modernization	4.13 (83%)
4	NM encourages the consumer on using renewable energy.	5.0 (100%)
5	Current energy modeling capabilities are adequate to meet NM needs.	3.6 (72%)
6	Modeling of grid dynamics, behavior, and performance.	3.0 (60%)
7	Modeling of energy efficiency.	3.54 (71%)
8	Modeling of techno-economic impacts of NM-based systems.	3.40 (68%)
9	Lack of technical knowledge regarding NM.	3.5 (70%)
10	Lack of sufficient data on NM.	3.2 (64%)
11	Lack of information and communication technologies (ICT) infrastructure.	3.67 (73%)
12	Lack of ICT to send monitoring data over real time.	3.67 (73%)
13	Extent to which your organization/self are involved in NM planning and domains.	3.67 (73%)
14	Provision of data	3.67 (73%)
15	Provision of expertise, research, or analysis.	3.07 (61%)
16	Model formulation and execution.	3.40 (68%)
17	Optimal NM planning for optimal systems for 25 years beyond license period.	5.0 (100%)
18	Fundamentals and basics of techno-economic models.	4.4 (88%)
19	NM analysis.	4.7 (93%)
20	NM pilot projects, testing, and implementation.	4.34 (87%)

Table 5. *Cont.*

Sr. #	Questions (Technical Perspective)	Response
21	Data management.	4.27 (85%)
22	Suitability of the modeling tools for NM planning and understanding.	4.13 (83%)
23	Resources Sharing	4.0 (80%)
24	Maintaining the best practices.	4.0 (80%)
25	Maintain the high standards and reduce mal practices	4.0 (80%)
26	Upgrade the knowledge pool.	4.0 (80%)
27	Resources utilization for national cause.	4.0 (80%)

Table 6. Stakeholders' survey from economics and financial perspective.

Sr. #	Questions (Economics and Finance)	Response
1	Awareness of various technical and financial models used for NM?	3.8 (76%)
2	NM improves the socio-economic status of prosumers.	4.20 (84%)
3	Modeling of integrated energy supply and demand planning and optimization.	3.13 (63%)
4	Modeling of energy finance.	3.27 (65%)
5	Modeling of concerned energy markets.	3.3 (67%)
6	NM rates should be more than or equal to the units purchased by National Grid.	5.0 (100%)
7	Inadequate resources and finance.	3.66 (73%)
8	Need for NM education regarding equipment quality and financial mechanisms?	5.0 (100%)
9	Financial support mechanisms	2.80 (56%)
10	Investment in financial model building.	4.27 (85%)
11	Investment in financial model implementation.	4.27 (85%)
12	Sharing of financial resources.	4.14 (83%)
13	Support by stakeholders for modeling technical and financial designs.	4.54 (91%)

Table 7. Stakeholders' survey from energy security and governance perspective.

Sr. #	Questions (Energy Security and Governance)	Response
1	NM improves the energy governance.	4.07 (81%)
2	NM improves future energy security and sustainability.	4.40 (88%)
3	Modeling of environmental, social, and political impacts of NM systems.	3.33 (67%)
4	Weak coordination among experts from different domains.	4.0 (80%)
5	Weak coordination among governmental institutions.	4.0 (80%)
6	Retention issues of trained personnel.	4.13 (83%)
7	Insufficient incentives and motivation.	3.73 (75%)
8	Administrative support.	3.13 (63%)
9	Environmental and social aspects of NM.	4.6 (92%)
10	Project management.	4.54 (91%)
11	Involvement in planning activities.	4.47 (89%)
12	Coordination with other research organizations and universities.	4.54 (91%)

Table 8. Stakeholders survey from stakeholders' engagement and capacity building perspective.

Sr. #	Questions (Stakeholders Engagement and Capacity Building)	Response
1	Industries can play a vital role in assisting NM policies.	4.0 (80%)
2	Importance of training for the organizations involved in NM planning.	4.0 (80%)
3	Machine learning and Artificial Intelligence.	4.13 (83%)
4	Long-range energy alternative planning and Energy Plan (EnergyPlan)	4.07 (81%)
5	Utilization of other concerned software.	4.47 (89%)
6	Coordination level among energy planning institutions and universities.	4.53 (91%)
7	Training on the process of data management.	4.53 (91%)
8	Training on the process model building.	4.53 (91%)

Table 8. *Cont.*

Sr. #	Questions (Stakeholders Engagement and Capacity Building)	Response
9	Training on the process implementation.	4.53 (91%)
10	Involvement in data management process.	4.34 (87%)
11	Sharing of human resources.	4.14 (83%)
12	Rate the need for stakeholders' engagement	4.0 (80%)
13	Accessibility to capacity building	4.0 (80%)
14	Coordination among stakeholders.	4.0 (80%)
15	Upgrading the capacity building programs.	4.0 (80%)
16	Increase the capacity building via training/short courses.	4.0 (80%)
17	Rate the favor and need for stakeholder's collaboration.	4.0 (80%)
18	Stakeholders to host various NM awareness and training events.	4.0 (80%)
19	Train professionals for future needs.	4.0 (80%)
20	Labs with high performance computers	4.4 (88%)
21	Long-term subscriptions to modeling software.	4.4 (88%)
22	Advanced training for faculty and key personnel.	4.6 (92%)
23	Capacity building courses from basic to expert level.	4.54 (91%)
24	Should stakeholders send concerned personal for training on NM aspects?	3.94 (79%)

4.2.2. Focused Group Discussions with Banks Representatives

Survey participants from the banking and financial sector included representatives from three institutions: Habib Bank Limited (HBL), State Bank of Pakistan (SBP), and Bank Alfalah. The questions and corresponding responses are presented below.

1. Is incentive scheme for renewable energy program (ISREP) extended by 2024?

HBL: Validity period has extended while other instructions remain unchanged.
SBP: It has been extended till June 2024 as of yet.
Bank Alfalah: Currently, temporary closed. Banks are financing on their standard markup rates.

2. What is the extension plans for Incentive scheme for renewable energy program (ISREP) in future?

HBL: It has extended by June 2024.
SBP: It has been extended till June 2024 as of yet.
Bank Alfalah: It will be extended in future. Currently, markup prices are very high.

3. Are financing streams/incentives schemes still available at 6% mark-up for Cat-II for solar and NM by SBP and other banks?

HBL: Yes. Maximum end user rate is 6%.
SBP: Yes, they are.
Bank Alfalah: In some of the cases, state bank is refinancing on 6% rates.

4. Do you think that the challenges and concerns faced by the users in Pakistan in availing concessionary financing from banks mainly goes around which of the following?

HBL: Major issue is economic conditions and import LC clearance.
SBP: Keeping proper financial record, good credit history and relationship with the bank.
Bank Alfalah: Shortage of funds.

5. Do you think that the normal public users in Pakistan can avail concessionary financing from banks for NM and solar installation at low or medium scale and high payback periods may be allowed from the banks?

HBL: Maximum tenure of financing is twelve years including maximum grace period of two years under Cat-I while maximum ten years for Cat-II and Cat-III.
SBP: Yes.
Bank Alfalah: Yes. High payback period must be granted so the average person can also avail this facility, as there is great shortfall in electricity resources.

6. Do you think that high interest rate of bank will negatively impact a normal person with average income regarding installation of PV based NM system if borrow the amount from bank?

HBL:	If consumer does not avail state banks scheme, commercial rates will be charged which are higher.
SBP:	Definitely, if not borrowed under the scheme.
Bank Alfalah:	Yes, high markup rates will affect general public as most of the people are salaried class and cannot afford standard markup rates offered by banks.

7. According to you, which sort of financial instrument will be suitable for Pakistan in Future? Such as feed-in-tariffs (FiTs), tax incentives, soft loans and grants, green bonds and crowd funding?

HBL:	Soft loans and grants. Green bond is another option.
SBP:	Tax incentives will be better.
Bank Alfalah:	Government should have to launch subsidized schemes with low rates and long-term repayment period.

4.3. Analysis of Methodology Contingent-3: Financing Mechanisms and Impact Analysis

4.3.1. Financial Streams from State Bank of Pakistan

In the context of Pakistan's financial landscape, the State Bank of Pakistan (SBP) has instituted a cost-effective method of financing aimed at bolstering green energy initiatives [40]. This financing approach, originally established in 2009 and revised in 2016, offers debt financing at a fixed and competitive interest rate of 6.00% per annum. The SBP extends this concessional financing to foster the growth of environmentally sustainable projects. The SBP channels funds to banks at an annual rate of 2%, and these financial institutions subsequently lend to end users at a 6% annual interest rate, thereby enjoying a spread of 4.00%.

Structured as a refinancing facility, the SBP engages in lending to both commercial banks and development finance institutions (DFIs) at the prevailing 2% interest rate [41]. These intermediaries then disburse the funds to end users at the aforementioned 6% interest rate, allowing them to capitalize on the 4.00% margin. The onus of sharing the burden of potential defaults rests with commercial banks, given their responsibility in the credit screening process for each individual end user. Consequently, commercial banks have proactively extended subsidized loans to large-scale renewable projects, encompassing utility-scale initiatives, as well as commercial and industrial ventures characterized by expansive rooftop installations. These loans are secured by collateral in the form of alternate assets and securities. For the implementation of distributed renewable energy systems, the SBP and other banks offer financing avenues in tandem with NM incentives. The financing schemes have been delineated across distinct categories, each catering to varying capacities and objectives illustrated in Table 9. To elucidate, Cat-II stands as the preeminent avenue for SBP-backed financing of NM projects, and this financial instrument is subsequently adopted by other banking institutions to operationalize similar mechanisms.

Table 9. SBP financial schemes as per categorizations [40,41].

Category-I (Cat-I)	
Scope:	Financing is accessible for renewable projects with capacities ranging from over 1 MW to 50 MW.
Net Metering:	Not applicable.
Maximum Tenure:	Financing terms span a maximum of 12 years, including a grace period of up to 2 years.
Creditor Limit:	A single entity may secure financing up to Rs. 6 billion at a 6% interest rate, excluding KIBOR.
Category-II (Cat-II)	

Table 9. *Cont.*

Scope:	Aligned with NEPRA's NM Regulations, financing is extended to renewable energy projects/solutions of around 1 MW.
Net Metering:	NM facilities are available, encompassing both self-consumption and surplus electricity sale to DISCOs.
Maximum Tenure:	The financing duration is capped at 10 years, with a grace period of up to 3 months.
Creditor Limit:	A singular entity can access financing up to Rs. 400 million at a 6% interest rate, without considering KIBOR.
Category-III (Cat-III)	
Scope:	Financing is targeted towards Renewable Energy Investment Entities (RE-IEs) exclusively, established to invest in renewable energy generation through project installations (~5 MW). These entities engage in selling electricity or engaging in deferred payment arrangements involving renewable energy equipment lease, rental, or sale to ultimate owners/users.
Net Metering:	Not applicable.
Maximum Tenure:	RE-IEs are eligible for financing up to a maximum of 10 years, along with a grace period of up to 6 months.
Creditor Limit:	The borrowing limit for a RE-IE is capped at Rs. 2 billion, carrying a 6% annual markup.

4.3.2. Current Financing Status of Banks under ISREP

In the realm of sustainable banking, significant progress has been observed, with 60% of banks having undertaken initiatives aligned with green banking guidelines. Among reporting banks, 55% have initiated actions focusing on environmental risk management, while 45% have established advisory services in accordance with the green banking framework. Notably, the majority of reporting banks have concentrated their efforts on the third theme of the green banking guidelines, namely "own impact reduction" or resource efficiency. This is indicative of a prevalent commitment towards mitigating their ecological footprint. Furthermore, a noteworthy trend is evident in the engagement of development finance institutions (DFIs) with green business guidelines [42]. Out of nine DFIs, six have embraced initiatives in this regard. However, the energy landscape in Pakistan remains skewed towards non-renewable sources [43]. A considerable 60% of electricity generation relies on thermal resources, while hydel sources contribute 30%, leaving renewables to contribute a modest 2.5%.

Intriguingly, the Incentive Scheme for Renewable Energy Program (ISREP) has been extended until 2024, with funds being reinvested into the scheme. As per reported figures until 2022, Bank Al-Habib leads ISREP borrowing with PKR 16.51 billion, followed by HBL (PKR 7.531 billion) and Bank of Punjab (PKR 6.3347 billion). Amidst these developments, HBL introduced a comprehensive social and environmental management system policy in 2015. The bank has set ambitious goals, aiming to eliminate exposure to exclusion-list industries, like tobacco, by 2025, and coal-related exposure by 2030.

The financing mechanisms depicted in Table A9 reveal that NM falls under Category II, enjoying a maximum tenure of 10 years and a markup rate capped at 6%. Cumulatively, the 15 banks have borrowed PKR 45.4351 billion through ISREP until September 2022. However, challenges persist in green financing. Systemic bottlenecks include fund reimbursement complexities, logistical delays, advanced payments to vendors, issues with independent power producer contracts, and the involvement of multiple agencies. In Figure 8a, these obstacles are visually captured. The status of DFIs' financing within ISREP until 2022 is presented in Table A10 and illustrated in Figure 8b. Notably, Pak-Kuwait ICL leads borrowing, accessing PKR 3.3942 billion out of a total of PKR 4.48551 billion obtained from SBP. In conclusion, this comprehensive overview sheds light on the progress, challenges, and opportunities within Pakistan's evolving green banking and renewable energy landscape.

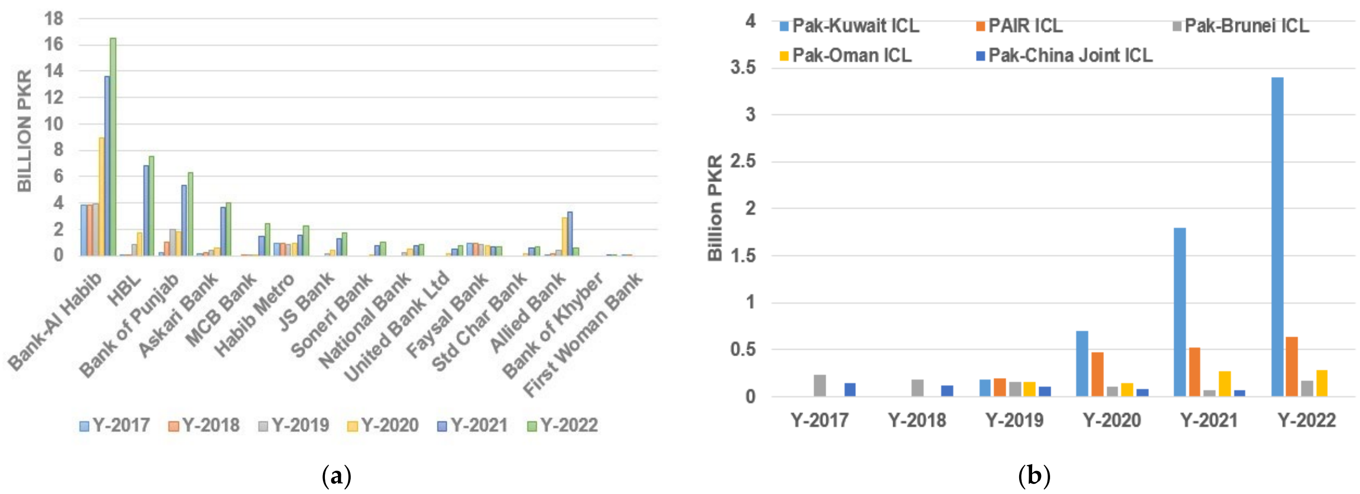


Figure 8. Current financing status and ranking of entities under ISREP until 2022: (**a**) banks, (**b**) DFIs.

4.3.3. Banking Financing Mechanism-Based Analysis

In light of recently announced amendments, it is imperative to conduct thorough research on future NM prospects while prioritizing the evaluation of financing requirements for Sustainable Building Practices (SBP). This study focuses on a 9 kW NM system, considering a capital cost of equipment at a rate of 200 PKR/Watt. The equipment costs include batteries (PKR 134,500), design and testing (PKR 50,000), grounding (PKR 50,000), solar modules (PKR 1,215,500), transportation and installation (PKR 100,000), electrical parts including cables (PKR 140,000), NM-related expenses (report, demand notice— PKR 100,000), and other charges (PKR 10,000), resulting in a net total of PKR 1,800,000. A decrease of 0.7% in production per year is considered, along with a bank mark-up of 6% excluding KIBOR.

This research evaluates three cases (Case-1: 70/30, Case-2: 75/25, Case-3: 80/20) based on different scenarios (S1 to S5: capital costs ranging from 200 PKR/Watt to 220 PKR/Watt) with an emphasis on payback periods and bank instalments. Notably, Case-1 demonstrates a feasible payback period within acceptable limits. However, as capital costs increase, payback periods rise from 5.02 to 7.74 years in Case-1, from 5.22 to 9.292 years in Case-2, and from 5.55 to 13.302 years in Case-3. The increasing bank instalments correspond to these extended payback periods. Importantly, Case-3 surpasses maximum payback period thresholds across all scenarios, including a 10-year grace period. Graphical representations in Figure 9a depict these results.

Considering three NM capacity cases (low: 10 kW, medium: 20 kW, high: 30 kW), further evaluation examines net profit, payback period, return on investment (ROI), and levelized cost of energy (LCOE) across different unit price scenarios (NAPPP ~19 PKR/kWh, average unit 14 PKR/kWh, NAEPP 9 PKR/kWh). Analysis in Figure 9b reveals that net profit is highest at an initial capital cost of 120 PKR/Watt with NAPPP ~19 PKR/kWh, diminishing significantly at 200 PKR/Watt and 220 PKR/Watt. Similarly, ROI trends exhibit a decrease across unit price scenarios. Figure 9c shows an upward trend in payback periods across increasing initial capital costs, with payback periods ranging from 4 to 15 years.

The financial evaluation of return on investment across NAPPP ~19 PKR/kWh, average unit ~14 PKR/kWh, NAEPP ~9 PKR/kWh is demonstrated in Figure 9d. The impact of LCOE on stakeholders is examined in Figure 9e. LCOE of the generated unit is lower than at NAPPP ~19 PKR/kWh, favoring consumers in terms of payback. However, rising system costs lead to elevated LCOE, potentially causing disparity between high LCOE and low unit rates, which could prove detrimental to stakeholders within the system.

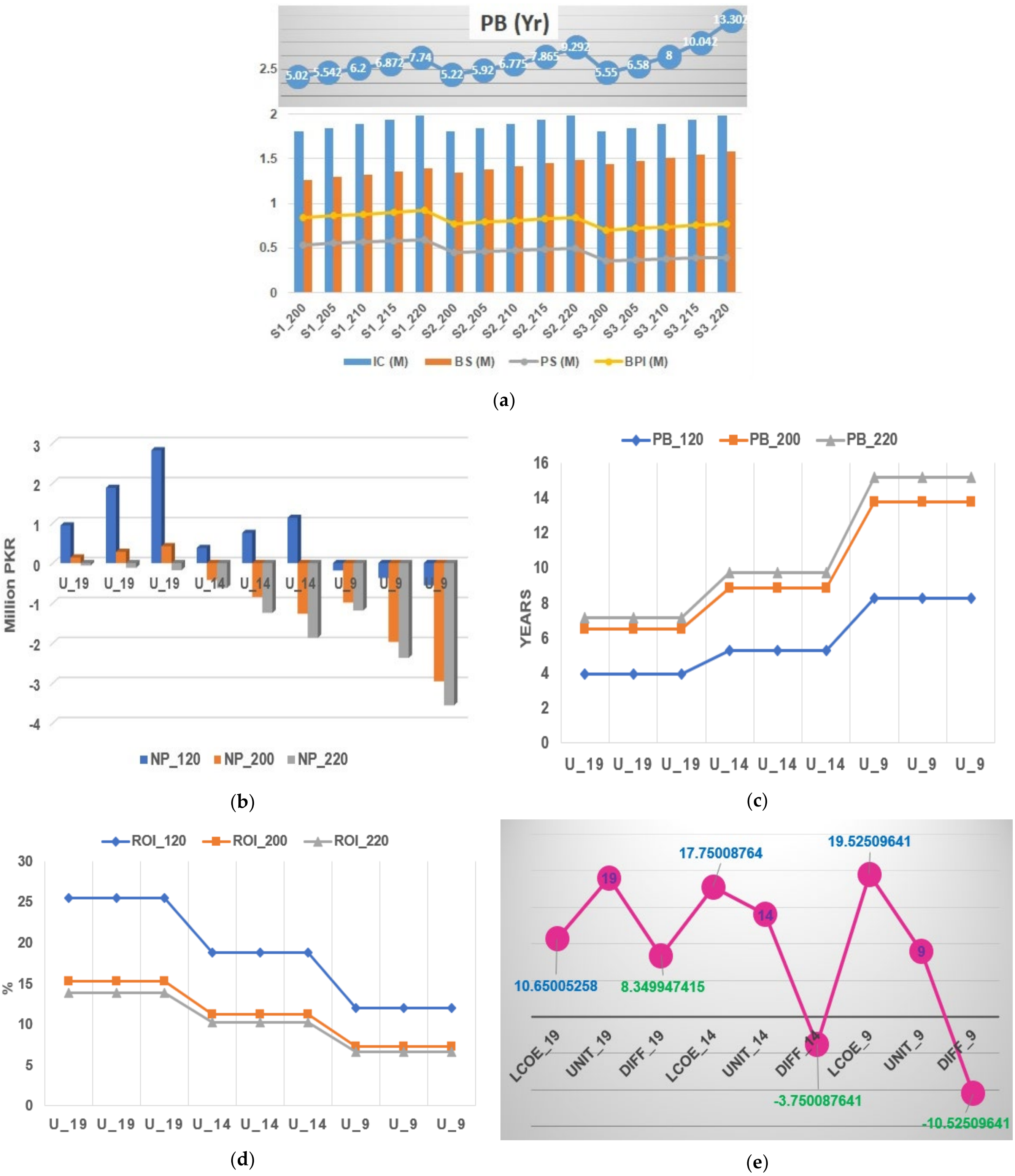


Figure 9. (**a**): Banking financing mechanism-based analysis at NAPPP ~19 PKR/kWh for 9 kW system only; (**b**) financial evaluation of net profit across NAPPP ~19 PKR/kWh, average unit ~14 PKR/kWh, NAEPP ~9 PKR/kWh, (**c**) financial evaluation of payback period in years across NAPPP ~19 PKR/kWh, average unit ~14 PKR/kWh, NAEPP ~9 PKR/kWh; (**d**) financial evaluation of return on investment across NAPPP ~19 PKR/kWh, average unit ~14 PKR/kWh, NAEPP ~9 PKR/kWh, (**e**) financial evaluation unit difference in terms of LCOE across NAPPP ~19 PKR/kWh, average unit ~14 PKR/kWh, NAEPP ~9 PKR/kWh.

4.3.4. Banking Sustainability Based Analysis

HBL spearheads the banking sustainability-based financing machanisms and can be considered as the gold standard, since they launched their first impact and sustainability report in 2021 subject to SDG-7, 9, 11, 12, and 13 [44]. The sustainability analysis is shown in self-descriptive form in Figure 10.

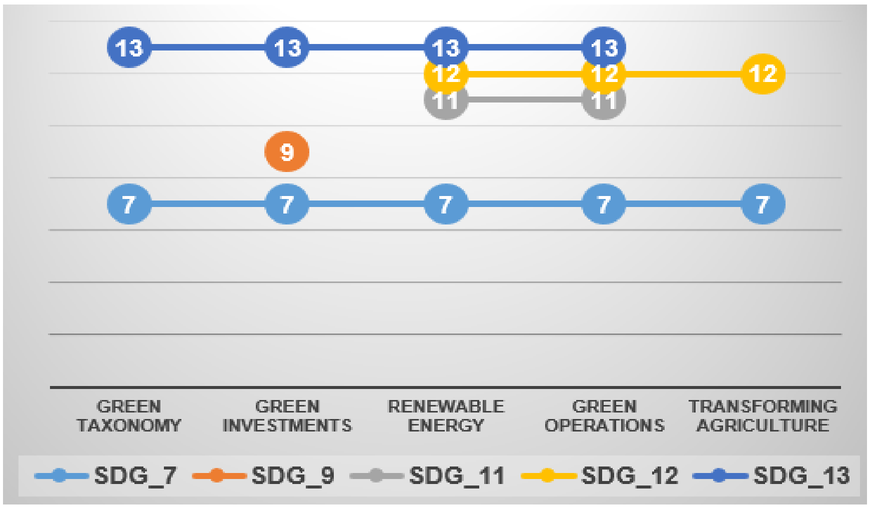


Figure 10. Banking sustainability-based analysis from HBL in SDGs.

5. Key Challenges in Availing Concessionary Financing

The analysis of the financing highlights several challenges and intricacies encountered by stakeholders seeking concessional financing for energy projects in Pakistan's banking landscape.

5.1. Financial Challenges of Renewable Project Funding

Owners of distributed generation projects are constrained to derive their economic viability primarily from the cost savings resulting from the shift from expensive grid energy to renewable sources. The feasibility of this shift depends on the implementation of NM or the ability to sell excess power back to the grid at favorable rates, coupled with extended licensing terms. Consequently, these investments typically entail protracted payback periods, and stakeholders encounter difficulties in sourcing appropriate project funding.

5.2. Enhancing National Energy Security

The nation's energy security and its vulnerability to shocks in the global energy market, which impact trade and fiscal balances, can be significantly ameliorated through the adoption of renewable energy solutions. Notably, utility-scale renewable energy projects enjoy equitable access to funding sources, including debt and equity avenues, akin to their non-renewable counterparts. This parity arises from a conducive regulatory environment that provides safeguards to these projects.

5.3. Techno-Economic Viability Analysis

Pakistan's single-buyer, take-or-pay electricity procurement strategy shields both renewable and non-renewable power ventures from specific commercial, macroeconomic, and technological obsolescence risks, rendering them creditworthy. However, the feasibility of distributed renewable energy projects, exemplified by residential rooftop solar solutions, is constrained by the absence of analogous single-buyer, take-or-pay assurances [45].

5.4. Policy Implications

The introduction of regulatory safeguards to enhance financial feasibility carries associated costs, impacting both governmental finances and end-consumer tariffs. This manifests as elevated electricity prices and an escalating government commitment to power subsidies.

5.5. Navigating Market Uncertainty and Utility Complexities

The burden of costly standby electricity, often reliant on imported fuels, and subsequently passed on to the broader consumer base, is primarily attributed to high-capacity prosumers. Escalating capital outlays have led to prolonged recovery periods beyond those stipulated by various financial institutions, compounded by the capital-intensive nature of standby power provisioning.

5.6. Financial Considerations amidst Prevailing Economic Realities

The prevailing economic conditions in 2023 have resulted in challenges when attempting to secure concessionary loans from banking establishments and development finance entities to facilitate project implementation. The prevailing economic climate introduces the risk of cost overruns, emerging as a primary obstacle to the seamless integration of NM initiatives across the supply chain [46].

To mitigate the risks posed by unforeseen cost escalations, stakeholders are advocating for the inclusion of standby financing mechanisms within the project's financial framework. Sponsors can execute this by engaging in project funds agreements, encompassing standby subordinated loans or equity commitments, thereby guaranteeing the timely completion of projects without disruption.

6. Conclusions and Policy Implications

This research paper offers a comprehensive assessment of the existing NM framework in Pakistan, with a specific focus on its operational mechanisms, financial incentives, and legislative structures. This study seeks to ascertain the prevailing challenges within the system and put forth policy suggestions to overcome these issues. Notably, this study emphasizes the role of the banking sector in facilitating net-metered connections. It underscores the substantial advancements made by Pakistan's NM program since its initiation in 2015. By April 2023, the program had successfully commissioned over 56,000 NM/distributed generation facilities, aggregating to an installed capacity of 950 MW. By May 2024, the number of NM consumers had increased to ~100,000 and a capacity of 1950 MW, almost doubling.

However, concerns arose among stakeholders when the NEPRA proposed amendments to the regulations in September 2022. These amendments posed a potential threat to the realization of the ambitious targets outlined in the IGCEP 2022–2031. Despite NEPRA retracting the proposed changes, it is imperative to avoid such hasty undertakings in the future. This is crucial to sustain stakeholder confidence and ensure the continued growth of the NM framework. Additionally, this study addresses the termination of the licensing regime for power generation, including NM, in April 2023, leaving a regulatory void. This gap bears significant ramifications for the power sector, particularly in the domain of power generation. To rectify this situation, NEPRA needs to devise a regulatory framework that provides stability and instills confidence in the industry

This study also delves into the perspective of the financing sector regarding NM. It reveals that 60% of banks have taken initiatives aligned with green banking guidelines, with a majority implementing measures to reduce their environmental impact. However, the financing sector encounters challenges in securing funding sources and optimizing resource allocation. The study proposes strategies to enhance resource allocation efficiency, evaluate the impact of pricing on metrics such as levelized cost of energy (LCOE), return on investment (ROI), and payback period (PBP), and establish a robust NM system for the future. To address these challenges, the report offers several policy recommendations.

- In the context of techno-economic aspects, recommendations are directed at optimizing resource allocation within the NM framework. To address the imbalanced distribution of NM participation between residential and industrial sectors, concerted efforts should be channeled towards enhancing NM deployment in the industrial sector. This would result in reduced electricity costs for industrial products. Pertaining to the disruption in the electricity balance, particularly in IESCO, effective NM planning is crucial, aligning optimal capacity installation with actual consumer loads. Clear communication from regulatory bodies, like NEPRA, regarding the cessation of the generation license regime is imperative. Conducting pre- and post-NM installation surveys, adjusting licensing regulations to include periodic visits, and establishing caps on high-capacity connections are advised. These short- to medium-term measures primarily target utilities and industries.
- In the context of stakeholder engagement, recommendations aim to increase NM integration through collaborative efforts. Focusing on socio-financial impacts, alignment with the IGCEP 2022–2031 framework is advocated. Special consideration is given to large-capacity consumers, who can influence payback mechanisms during peak demand periods. Encouraging technological innovations, like peer-to-peer communication and blockchain, can incentivize grid support and trading. The transition from NAPPP to NAEPP should be carefully phased in to maintain economic viability. NM planning is emphasized for meeting national energy mix targets, enhancing energy governance, and bolstering energy security. Closer ties between energy stakeholders and academia are sought, fostering shared knowledge and resources for effective NM modeling.
- In the context of financing mechanisms, strategies should be provided to address challenges in green financing. Issues like reimbursement difficulties, logistics delays, and supply chain disruptions must be urgently resolved. To improve accessibility to financing, banks should diversify their offerings tailored to various NM project types. Government subsidies, tax incentives, and green financing frameworks are suggested to incentivize investment. Collaboration between government, financial institutions, and the private sector is advocated through public–private partnerships and microfinance initiatives. The enhancement of the State Bank of Pakistan's financing scheme and the issuance of green bonds or renewable energy funds are put forth as viable options. Capacity building for banks, guarantee mechanisms, research sharing, and the establishment of a database for successful projects will enhance the financing landscape for NM projects.

Finally, this study underscores the significance of a well-functioning NM ecosystem in Pakistan. It highlights the potential of this framework to contribute to the country's energy objectives and diminish dependence on non-renewable energy sources. By addressing the identified challenges, adopting the proposed policy suggestions, and harnessing the potential of the banking sector, Pakistan can unlock the complete potential of NM, thereby paving the way for a more resilient and sustainable energy future. The limitation of the study is that data until January 2023 were considered, and, in future work, an extensive study across various tariff regimes will be considered encapsulating the 2030 planning horizon year.

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List of Abbreviations

CTBCM	Competitive Trading Bilateral Contract Market
DFIs	Development Finance Institutions
DISCO	Distribution Company
EPP	Energy Purchase Price
EYB	Energy Yearbook
FDI	Foreign Direct Investment
FESCO	Faisalabad Electric Supply Company Limited
FY	Financial Year
GBG	Green Banking Guidelines
GDP	Gross Domestic Product
GOP	Government of Pakistan
GST	General Sales Tax
GWh	Gigawatt hours
HESCO	Hyderabad Electric Supply Company Limited
IESCO	Islamabad Electric Supply Company Limited
IFI/IFC	International Finance Institutions/Corporations
IGCEP	Indicative Generation Capacity Expansion Plan
IPP	Independent Power Producer
ISREP	Incentive Scheme for Renewable Energy Program
KE	K-Electric Limited
kV/KVA	Kilo Volt/Kilovolt Ampere
kWh	Kilowatt hours
LESCO	Lahore Electric Supply Company Limited
MEPCO	Multan Electric Power Company Limited
MVA	Megavolt Ampere
MW	Megawatt
MWh	Megawatt hours
MYT	Multi-year Tariff
NAEPP	National Average Energy Purchase Price
NAPPP	National Average Power Purchase Price
NEPRA	National Electric Power Regulatory Authority
NM	Net Metering
NPCC	National Power Control Centre
NTDC	National Transmission and Dispatch Company Limited
O&M	Operation and Maintenance
PBP	Payback Period
PAEC	Pakistan Atomic Energy Commission
PEPCO	Pakistan Electric Power Company Limited
PESCO	Peshawar Electric Supply Company Limited
PPA	Power Purchase Agreement
PPIB	Private Power and Infrastructure Board
QESCO	Quetta Electric Supply Company Limited
SCADA	Supervisory Control and Data Acquisition
SEPCO	Sukkur Electric Power Company Limited
T&D	Transmission and Distribution
TESCO	Tribal Area Electricity Supply Company Limited
WAPDA	Water and Power Development Authority

Appendix A

Table A1. Overall capacity and relevant financial evaluations from 2016 until 2023 across NAPPP.

NAPPP	R_Low	CC_Low	NP_Low	R_Med	CC_Med	NP_Med	R_High	CC_High	NP_High
2016	**5.84**	5.04	**0.8**	**11.9**	5.136	**6.764**	**145.822**	125.862	**19.96**
2017	**35.77**	32.806	**2.97**	**16.431**	15.07	**1.3626**	**48.717**	44.677	**4.04**
2018	**234.63**	98.64	**136**	**73.23**	30.784	**42.442**	**163.73**	68.832	**94.9**
2019	**896.27**	397.72	**498.55**	**339.42**	150.62	**188.8**	**217.4**	96.47	**120.93**
2020	**1676.1**	772.7423	**903.3384**	**769**	354.54	**414.455**	**1260**	581	**679**
2021	**3209.32**	1574.055	**1635.27**	**1952.42**	957.59	**994.83**	**1500.23**	735.81	**764.42**
2022	**211.62**	108.7345	**102.89**	**357**	183.42	**173.58**	**2789.43**	1433.26	**1356.2**
2023 *	**2.10016**	1.962	**0.1382**	**24.953**	23.311	**1.6415**	**189.96**	177.46	**12.496**

* Data until 31 January 2023.

Table A2. Overall capacity and relevant financial evaluations from 2016 until 2023 across NAEPP.

NAEPP	R_Low	CC_Low	NP_Low	R_Med	CC_Med	NP_Med	R_High	CC_High	NP_High
2016	**5.84**	5.04	**0.8**	**11.9**	5.136	**6.764**	**145.822**	125.862	**19.96**
2017	**35.7724**	32.806	**2.97**	**16.431**	15.07	**1.3626**	**48.717**	44.677	**4.04**
2018	**199.3464**	98.64	**100.71**	**62.214**	30.784	**31.43**	**139.111**	68.832	**70.28**
2019	**694.37**	397.72	**296.65**	**262.962**	150.62	**112.343**	**168.424**	96.47	**71.955**
2020	**1157.149**	772.7423	**384.406**	**530.9**	354.54	**176.367**	**869.82**	581	**288.96**
2021	**2003.3**	1574.055	**429.2**	**1218.72**	957.59	**261.13**	**936.46**	735.81	**200.652**
2022	**100.24**	108.7345	**−8.5**	**169.1**	183.42	**−14.3265**	**1321.03**	1433.26	**−111.95**
2023 *	**0.9948**	1.962	**−0.9672**	**11.82**	23.311	**−11.491**	**89.98**	177.46	**−87.48**

* Data until 31 January 2023.

Table A3. Comparative capacity and relevant financial evaluations for 2016–2023 across NAPPP and NAEPP.

NAPP	R_Total	CC_Total	NP_Total	NAEPP	R_Total	CC_Total	NP_Total
2016	**163.561**	125.5615	**37.7**	2016	**163.5615**	125.862	**37.7**
2017	**100.92**	92.55	**8.37**	2017	**100.92**	92.55	**8.37**
2018	**471.583**	198.252	**273.331**	2018	**400.672**	198.25	**202.42**
2019	**1453.1**	644.8	**808.3**	2019	**1125.76**	644.81	**480.95**
2020	**3705**	1708.14	**1996.86**	2020	**2557.87**	1708.14	**849.72**
2021	**6662**	3267.5	**3394.5**	2021	**4158.5**	3267.45	**891.05**
2022	**3358**	1725.4	**1632.6**	2022	**1590.64**	1725.41	**−134.8**
2023 *	**217.0078**	202.732	**14.276**	2023*	**102.8**	202.7	**−100.1**

* Data until 31st January 2023.

Table A4. Overall averaged capacity and relevant MWh evaluations from 2016 until 2023.

Year	Low <11 KW (Avg Cap)	Medium <25 KW (Avg Cap)	High 25 KW> (Avg Cap)	Low <11 KW MWh	Medium <25 KW MWh	High 25 KW > MWh
2016	6.3	16.05	361.52	26.944	68.643	1546.15
2017	6.225	16.12	87.6	30.367	78.637	427.333
2018	6.94	14.87	76.48	78.197	167.549	861.742
2019	7.52	15.1	44.2	84.732	170.14	498.03
2020	7.561	15.9	123.588	85.183	179.154	1392.67
2021	7.83	15.35	66.74	88.225	172.96	752
2022	8.17	17.015	109.5	92.056	191.661	1233.8
2023 *	9.81	16.65	80.6632	110.535	187.605	908.88

* Data until 31st January 2023.

Table A5. Overall averaged capacity-based relevant financial evaluations (NAPPP) for 2016–2023.

NAPP	R_Low	CC_Low	NP_Low	R_Med	CC_Med	NP_Med	R_High	CC_High	NP_High
2016	**0.512**	0.504	**0.08**	**1.30421**	1.284	**0.02021**	**29.377**	28.922	**0.455**
2017	**0.577**	0.53	**0.048**	**1.4941**	1.3702	**0.124**	**8.12**	7.45	**0.6733**
2018	**1.5053**	0.6246	**0.8807**	**3.2253**	1.3383	**1.887**	**16.59**	6.8832	**9.70533**
2019	**1.61**	0.7144	**0.896**	**3.233**	1.4345	**1.8**	**9.4625**	4.2	**5.2635**
2020	**1.6185**	0.756	**0.8625**	**3.40393**	1.59	**1.814**	**31.483**	14.71	**16.78**
2021	**1.69833**	0.8222	**0.8762**	**3.33**	1.612	**1.718**	**14.476**	7.0077	**7.47**
2022	**1.749**	0.8987	**0.8504**	**3.642**	1.8711	**1.77**	**23.442**	12.045	**11.397**
2023 *	**2.10016**	1.962	**0.1382**	**3.5645**	3.33	**0.2345**	**17.27**	16.133	**1.137**

* Data till 31 January 2023.

Table A6. Overall averaged capacity-based relevant financial evaluations (NAEPP) for 2016–2023.

NAEPP	R_Low	CC_Low	NP_Low	R_Med	CC_Med	NP_Med	R_High	CC_High	NP_High
2016	**0.512**	0.504	**0.08**	**1.30421**	1.284	**0.02021**	**29.377**	28.922	**0.455**
2017	**0.577**	0.53	**0.048**	**1.4941**	1.3702	**0.124**	**8.12**	7.45	**0.6733**
2018	**1.2623**	0.6246	**0.6377**	**2.705**	1.3383	**1.367**	**13.911**	6.8832	**7.028**
2019	**1.2473**	0.7144	**0.5329**	**2.5045**	1.4345	**1.07**	**7.33**	4.2	**3.13**
2020	**1.1308**	0.756	**0.3761**	**2.381**	1.59	**0.791**	**18.51**	14.71	**6.15**
2021	**1.0463**	0.8222	**0.2242**	**2.0513**	1.61175	**0.4395**	**8.9187**	7.0077	**1.911**
2022	**0.8285**	1.634	**−0.8255**	**1.725**	3.402	**−1.677**	**11.1**	12.045	**−10.8**
2023 *	**0.9948**	1.962	**−0.9672**	**1.69**	1.915	**−0.225**	**8.18**	16.133	**−1.1**

* Data until 31 January 2023.

Table A7. Bank financing mechanisms (assessed from respective websites).

Parameters	SBP	Bank Al Habib	Soneri Bank	Faysal Bank	JS Bank	Meezan Bank
Capacity (MW)	Upto-1 MW	Upto-1	0.004–1	0.004–0.02	-	1
Target Consumers	AB, SME, Residential, commercial	AB, SME, Residential, commercial	AB, SME, Residential, commercial	Residential	Residential only	Residential only
Program Name	SBP Scheme for Renewable Energy	-	Soneri Renewable Energy Finance	Faysal Islami Solar Solutions	JS Ghar Apna Solar Solution	Mera Pakistan Mera Ghar
Eligibility	Ownership of premises only, only vendor based	Bank Statement of last 1 year, NOC from owner, electricity bill of last 1 year	Banking account in soneri Bank, Age (25–65), Vendor Based	Age (21–60), Minimum salary of 100 k PKR	Ownership of home, Account in JS bank, Authorized Vendors	Approved vendors only, Bank account statement
Loan Limit(M)	400	1.5–400	3–5	0.1–3	0.3–3.5	0.1–2
Debt Ratio	80/20	75/25	80/20	85/15	80/20	85/15
Tenure (Years)	10	10 + 0.25	10	07	3–7	1–5
Security	Undertaking of ultimate owner, Lease agreement	-	Property Mortgage for financing above Rs. 3 Million	-	-	-
Category	II	II	II	II	II	II
Mark up (%)	6	6	3–5	6	6	6

Table A8. Current financing status of banks and ranking under ISREP until 2022–2023.

Amount (Billion PKR)/Year	Y-2017	Y-2018	Y-2019	Y-2020	Y-2021	Y-2022	Rank of Bank
Bank-Al Habib	3.885	3.885	3.947	8.959	13.589	**16.51**	**1**
HBL	0.07	0.105	0.831	1.716	6.805	**7.531**	**2**
Bank of Punjab	0.242	1.025	2.011	1.859	5.347	**6.3347**	**3**
Askari Bank	0.126	0.224	0.43	0.579	3.673	**4.008**	**4**
MCB Bank	0	0.028	0.085	0.075	1.443	**2.455**	**5**
Habib Metro	0.971	0.963	0.845	0.983	1.593	**2.248**	**6**
JS Bank	0	0	0.134	0.433	1.322	**1.71**	**7**
Soneri Bank	0	0	0	0.08	0.809	**0.987**	**8**
National Bank	0	0	0.236	0.481	0.74	**0.816**	**9**
United Bank Ltd.	0	0	0	0.147	0.513	**0.761**	**10**
Faysal Bank	0.971	0.963	0.897	0.81	0.718	**0.67**	**11**
Standard Chartered Bank	0	0	0	0.144	0.593	**0.6814**	**12**
Allied Bank	0.013	0.159	0.426	2.898	3.331	**0.617**	**13**
Bank of Khyber	0	0	0	0	0.054	**0.106**	**14**
First Woman Bank	0.087	0.078	0	0	0	**0**	**15**
Total (Borrowing) ISREP	**6.365**	**7.43**	**9.842**	**19.164**	**40.53**	**45.4351**	**From SBP**

Table A9. Current financing status of DFIs and ranking under ISREP until 2022–2023.

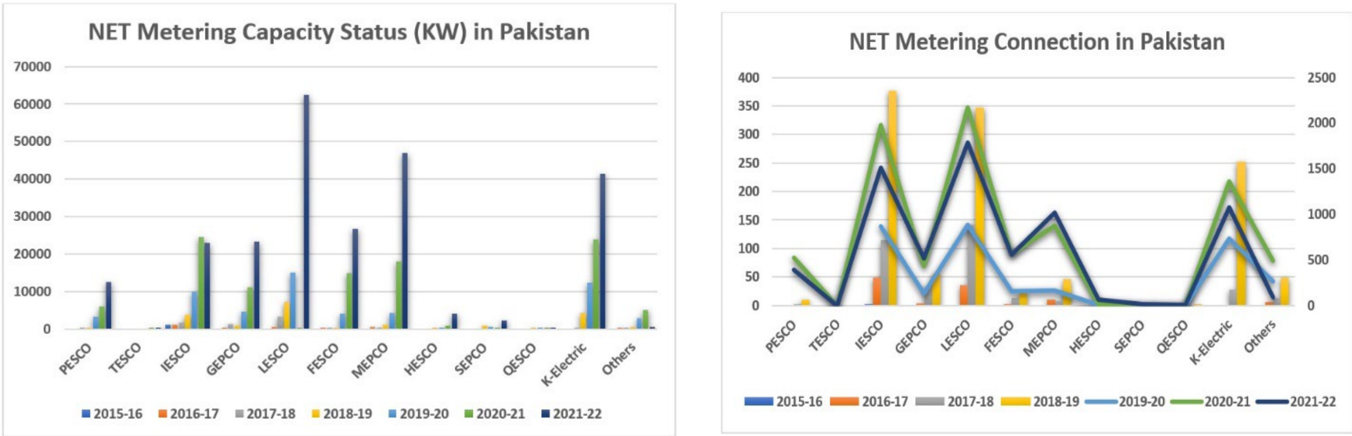
DFI	Y-2017	Y-2018	Y-2019	Y-2020	Y-2021	Y-2022	Rank of DFI/IFI
Pak-Kuwait ICL	0	0	0.18	0.694	1.7986	3.3942	**1**
PAIR ICL	0	0	0.194	0.479	0.52043	0.636	**2**
Pak-Brunei ICL	0.229	0.183	0.153	0.105	0.066	0.17531	**3**
Pak-Oman ICL	0	0	0.159	0.14	0.266	0.28	**4**
Pak-China Joint ICL	0.15	0.123	0.102	0.081	0.064422	- *	**5**
Total (Borrowing) SBP	0.379	0.306	0.788	1.499	2.715452	4.48551	**From SBP**

* Not available online [extracted from annual reports].

Table A10. Banking financing mechanism-based analysis.

Bank Case	Scenario (Rs/Watt)	Initial Capital (IC) (M-PKR)	Bank Share (BS) (M-PKR)	Personal Investment (PI) (M-PKR)	Bank Payment Installment (M-PKR)	Average Payback (Years)
Case-1 70/30 (%)	S1_200	1.8	1.26	0.54	0.299119	5.02
	S2_205	1.845	1.2915	0.5535	0.306597	5.542
	S3_210	1.89	1.323	0.567	0.314075	6.2
	S4_215	1.935	1.3545	0.5805	0.321553	6.872
	S5_220	1.98	1.386	0.594	0.329031	7.74
Case-2 75/25 (%)	S1_200	1.8	1.35	0.45	0.320485	5.22
	S2_205	1.845	1.38375	0.46125	0.328497	5.92
	S3_210	1.89	1.4175	0.4725	0.336509	6.775
	S4_215	1.935	1.45125	0.48375	0.344522	7.865
	S5_220	1.98	1.485	0.495	0.352534	9.292
Case-3 80/20 (%)	S1_200	1.8	1.44	0.36	0.341851	5.55
	S2_205	1.845	1.476	0.369	0.350397	6.58
	S3_210	1.89	1.512	0.378	0.358943	8
	S4_215	1.935	1.548	0.387	0.36749	10.042
	S5_220	1.98	1.584	0.396	0.376036	13.302

Appendix B



(**a**) (**b**)

Figure A1. NM trends in Pakistan from 2015–2016 until 2021–2022: (**a**) capacity (kW), (**b**) connections.

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