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Solar Net Metering: Status, Prospects and Scaling Challenges

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Acronyms

AEDB	Alternative Energy Development Board
BEPZA	Bangladesh Export Processing Zone Authority
EPZs	Export Processing Zones
IEA	International Energy Agency
IPP	Independent Power Plant
IRENA	International Renewable Energy Agency
KEPZ	Korean Export Processing Zone
KII	Key Informant Interview
MCPS	Mujib Climate Prosperity Plan
NEM	Net Energy Metering
NMS	Net Metering Systems
NPV	Net Present Value
PSMP	Power System Master Plan
SDGs	Sustainable Development Goals
SREDA	Sustainable And Renewable Energy Development Authority
WACC	Weighted Average Cost of Capital

Executive Summary

This particular study aims to assess the current status of solar-based net metering systems in Bangladesh and explore their potential for driving a renewable energy transition. The specific objectives included examining the current status of net solar system installations, evaluating the cost-benefit of implementing net-meter based solar systems in industrial premises, and exploring the scalability of such installations in Export Processing Zones (EPZs).

Despite being a relatively new concept in Bangladesh, net metering has gained traction globally, prompting a detailed examination of practices in countries like the United States, selected European nations, India, Sri Lanka, and Pakistan. Since its adoption in 2018, the Net Energy Metering Guideline has significantly contributed to the expansion of renewable energy, with 2015 solar net metering systems installed by 2023. These systems were predominantly installed in commercial buildings (55%), followed by residential (28%) and industrial (16%) structures.

The study projected the energy generation and CO2 emission reduction potential of these systems, with industrial installations expected to lead, generating 52.6% of total energy and contributing equally to CO2 emission reduction. A comprehensive cost-benefit analysis revealed that investment arrangement A, leveraging BB's refinancing facility, yielded the highest positive net present value (NPV) equivalent to USD 0.75 million, emphasizing the critical role of financing in promoting sustainable investments.

Furthermore, simulation results underscored the potential impact of implementing Net Energy Metering (NEM) in EPZs, suggesting that utilizing 20-30% of industrial plot areas for solar PV-based Net Metering Systems (NMS) could add 222 MW to 333 MW of renewable energy capacity to the national grid. This analysis highlights the importance of integrating renewable energy solutions within industrial zones to enhance energy sustainability and reduce reliance on non-renewable sources.

This study advocates for the promotion of Net Energy Metering (NEM) systems, particularly targeting industrial clusters. It emphasizes the critical importance of coordination between the Bangladesh Power Export Zones Authority (BPEZA) and the Sustainable and Renewable Energy Development Authority (SREDA) to expedite NEM implementation in industrial clusters, including upcoming economic zones. Currently, NEM systems are predominantly installed in buildings with three-phase connections, warranting further research and pilot activities to enhance technical efficiency.

While SREDA focuses on promoting NEMs in urban residential and commercial buildings, it's essential to recognize the significant potential in rural areas, characterized by ample rooftop spaces and south-facing houses. Strategically, SREDA should consider expanding its efforts to penetrate sub-urban and rural regions. Additionally, to enhance financial feasibility, community-level operational and capital expenditure (OPEX and CAPEX) setups should be explored.

By capitalizing on these recommendations, stakeholders can develop targeted strategies to expedite the deployment of solar-based net metering systems, ultimately contributing to a more sustainable energy future for the nation

Section I: Introduction

In 2021, Bangladesh has already made a significantly stride forward in meeting its commitment under Sustainable Development Goals (SDGs) by ensuring 100% access to electricity for the entire population, as reflected in SDG indicator 7.1.1. The next challenge for Government of Bangladesh (GoB) is to achieve affordable and clean energy under SDG 7. As of January 2024, Bangladesh's installed electricity generation capacity has reached to 29,265 MW with only 1,203 MW generated from renewable energy sources, constituting a mere 4.1% of the total capacity (SREDA, 2024). Despite this low proportion, the government has committed to produce 40% of its electricity from renewable sources. The Renewable Energy Policy (REP) of 2008 initially aimed for 5% electricity generation from renewables by 2015, a goal that went unfulfilled. Nonetheless, the Power Sector Master Plan (PSMP) of 2016 expressed optimism, setting a new target of achieving 10% electricity generation from renewable sources by 2020; that too remain unmet. The historical challenges of meeting the previous targets make the current 40% commitment seem particularly ambitious but some critics believe that this ambitious goal could eventually accelerate Bangladesh's transition to renewable energy. Looking ahead, the GoB envisions the future of electricity generation from renewable sources to be dominated by solar energy. In alignment with this vision, the GoB has approved 8 new solar parks, and upon full implementation, these projects will add a total of 435.3 MW install capacity to the national grid. Furthermore, an additional 23 solar parks totaling 1424.3 MW are currently in the planning phase. In addition to the establishment of solar parks, the promotion of solar systems through initiatives like 'net metering rooftop solar' is high on the policy agenda (SREDA, 2022).

The introduction of the net metering guideline in Bangladesh in 2018 aimed to encourage the consumption of renewable energy. Recognizing consumers as prosumers (consumers are producers as well), the policy incentivizes them to install more solar plants in their rooftops and premises. Prosumers can sell excess electricity to the national grid or import an equivalent amount, with the consumer's bill calculated on an aggregated basis, adjusting the net amount of electricity. As of December 2023, nearly 85.3 MWp of installed capacity has been added to the national grid through net metering arrangements (SREDA, 2024). Renewable energy advocates and related industry experts consider net metering to be a crucial element of a carbon-free energy portfolio and a more robust power infrastructure (Stoutenborough & Beverlin, 2008). Given, net metering systems may prove instrumental towards scaling up Bangladesh’s effort to meet generation of clean electricity from renewable sources, this particular study is to examine the status, prospects, and scaling challenges of net energy metering in Bangladesh.

1.1 Objective of the Study

The overarching objective of the study is to examine the current status of solar based net metering system and explore the potential of a renewable energy transition through scaling up this system, and discuss possible avenues for execution.

The specific objectives are the following:

(a) Examine the current status of ‘net solar system installments’

(b) Assess the cost-benefit of setting a net-meter based solar system in the industrial premises

(c) Explore the potential of scaling up net solar system installments in export processing zones (EPZs)

1.2 Organization of the Report

The present paper comprises an introduction and six additional sections. Section 2 offers an extensive literature review on 'net metering systems' across selected countries. Section 3 outlines the methodology and data employed in this study. Section 4 provides a descriptive analysis of the current status of solar-based net metering systems. In Section 5, the net present value (NPV) of capital investment is revealed for industrial buildings, followed by further discussions based on the findings. Section 6 explores the potential of scaling up net solar system installations in EPZs. Prior to concluding and highlighting the main findings in Section 7, relevant policy issues are discussed based on the study's findings.

Section II: Literature Review on Net-Metering Systems by Selected Countries

While net metering is a relatively new concept in Bangladesh, it has been widely adopted by many other countries for a considerable period. This section outlines the diverse landscape of net metering practices across different regions, with a focus on the United States, selected European countries, India, Sri Lanka, and Pakistan.

2.1 United States

In the United States, net metering regulations were established by most states during the late 1900s. According to a study by Smith et al. in 2021, utilities across the United States served approximately 2.4 million net metering customers in 2020, with the majority from the residential sector, relying on solar net metering—accounting for about 2.3 million customers. Different states in the U.S. have implemented varying compensation rates and schemes for customers engaging in net metering and selling surplus electricity back to utilities (Davies & Carley, 2017; Solar Energy Industries Association, 2017). For instance, in California, prosumers are compensated through a Net Surplus Compensation (NSC) rate for the surplus electricity they contribute to the grid. This rate, roughly between USD 0.04 to USD 0.05 per kWh, aligns with the continuous 12-month average market rate for energy. Additionally, prosumers with facilities under 1 MW in California incur a one-time interconnection fee and cover the costs of distribution system upgrades. They are also required to adopt a Time-of-Use (TOU) rate to participate in NEM 2.0 and pay non-bypassable charges in every metered interval (California Public Utilities Commission, 2023). In contrast, Arkansas' approach involves billing net metering customers monthly based on a standard rate schedule and any applicable supplement schedules. The state allows a 12-month period for the rollover of kilowatt-hour credits earned by consumers for net energy generation (Arkansas Public Service Commission, 2007).

2.2 Selected European Countries

2.2.1 Denmark

In Denmark, solar net metering operates on an hourly basis, providing compensation to prosumers for both self-generation and consumption. This compensation may involve partial or complete exemptions from specific tariffs and taxes (Martín *et al.*, 2021). According to the Danish BEK 999/2016 Regulatory Framework, solar photovoltaic (PV) systems with a capacity exceeding 50 kW receive a partial Public Service Obligation (PSO) exemption. On the other hand, facilities with a capacity equal to or less than 50 kW enjoy a full PSO exemption under this regulatory framework.

2.2.2 Italy

In 2009, the Italian government instituted net metering regulations, known as Scambio sul Posto. According to this framework, individual plants must adhere to a maximum limit of 500 kW, irrespective of the technology employed. Prosumers are entitled to monetary compensation determined by the formulas outlined in Article 6 of Regulation 570/2012 when their energy contributions to the grid exceed their consumption. Tariffs are assessed annually, and each net metering agreement involves a fixed charge of EUR 30 along with a variable fee of EUR 1/kW for systems ranging from 20 kW to 500 kW. Additionally, systems with a capacity exceeding 3 kW are obligated to remit a fee to GSE (Gestore dei Servizi Energetici) to cover management, verification, and control costs (Schwarz, 2019).

2.2.3 Netherlands

In 2004, the Netherlands introduced net metering as an incentive for homeowners to invest in solar panels. However, those exceeding the annual 3,000 kWh cap for electricity export were ineligible for net metering for the remainder of the calendar year. By 2011, the export limit was increased to 5,000 kWh (Ecofys Netherlands BV, 2012). Some utility providers even offered additional net metering beyond the mandated cap.

As of February 9, 2023, the Dutch parliament was contemplating a gradual phase-out of the net metering scheme, set to commence in 2023 (Bellini, 2023). Subsequently, the new Dutch government announced a postponement of changes to the net metering regulations until 2025. The existing net metering scheme values each kilowatt-hour (kWh) of electricity fed back into the grid on par with a kWh consumed from the grid. The annual bill offsets the power fed back against the power consumed, and any surplus electricity fed into the grid may receive lower compensation, which varies by energy supplier. As the scheme phases out from 2025 onward, the compensation for feed-in power is anticipated to be significantly lower than the cost of consumed power (Berg, 2023).

2.3 India

In India, net metering regulations vary from state to state, akin to the United States. According to the Andhra Pradesh Solar Power Policy (2015), consumers in domestic, commercial, and industrial sectors have the flexibility to install facilities up to 1000 kWp at a single location, either on a gross or net metering basis. Solar Rooftop Photovoltaic (SRP) systems with capacities up to 56 kW are connected at the Low Tension (LT) level of the distribution network, while those with capacities exceeding 56 kW up to 1000 kW are connected at either the 11 kV or 33 kV level of the distribution network (APSPDCL, 2015). Consumers are compensated using an average pooled purchase cost (APPC) rate for any surplus electricity they contribute to the grid. Additionally, a 20% subsidy of the capital cost is available for 3-phase service customers in the domestic sector, up to 3 kW (Goel, 2016). Projects established within the policy's validity period can benefit from these arrangements for a duration of 25 years.

In contrast, in Tamil Nadu, the installed photovoltaic capacity is capped at the sanctioned load, and it is recommended to size the system in a way that annual generation stays within 90% of annual consumption (TEDA, 2014). The measurement of energy import and export is facilitated by bidirectional energy meters or import-export energy meters.The incentive structure in Tamil Nadu includes INR 2 per kWh for the initial two years, followed by INR 1 per kWh for the subsequent two years, and finally, INR 0.5 per kWh for the succeeding two years (Goel, 2016).

2.4 Sri Lanka

Sri Lanka stands among the early developing nations to champion free net metering, introducing a system where the only associated cost is the initial one-time fee for a net meter and protective equipment to ensure power stability during outages (PUCSL, 2017). Customers falling under the Ceylon Electricity Board (CEB) and the Lanka Electricity Company (LECO) have the option to obtain a 10-year net metering permit, with the condition that the power generation facility's capacity remains below 1000 kVA. According to Abeywickrama et al. (2022), Sri Lanka employs net metering, net accounting, and net plus to harness energy from grid-connected solar panels. In the net metering system, customers cannot sell excess electricity to the grid; instead, they receive energy credits in kilowatt-hours (kWh) for their surplus, enabling them to offset future consumption. These credits can be carried forward from one billing period to the next, typically within a month (PUCSL, 2017). In the case of net accounting and net plus, consumers receive Rs 22 per unit for the initial 7 years and Rs 15.50 for the subsequent 13 years, totaling 20 years. The net plus concept severs the link between consumer grid electricity use and solar-generated grid electricity. Put simply, consumers receive monetary compensation for supplying electricity to the grid, irrespective of their grid consumption (PUCSL, 2021).

2.5 Pakistan

Distributed Generation and Net Metering Regulations were introduced in Pakistan by the National Electric Power Regulatory Authority Alternative and Renewable Energy (NEPRA ARE) in 2015. According to these regulations, prosumers with capacities ranging from 1 kWp to 1 MWp are required to utilize either a standard bi-directional meter or two separate meters – one for electricity purchase and the other for selling electricity to the Distribution Company (DISCO). The overall Net Energy Metering (NEM) procedure typically takes up to three and a half months, on average, for complete implementation. The net export limit is set at up to 1 MW. Moreover, in 2018, the Alternative Energy Development Board (AEDB) compiled a net metering handbook. This handbook serves as a guide for DISCOs to reference when processing applications for net metering in accordance with the established regulations. It provides valuable insights for both applicants and DISCOs involved in the net metering process.

This review highlights the varied landscape of net metering practices across diverse regions. In the United States, widespread regulations govern net metering, catering to millions with varying compensation structures. European nations showcase distinct approaches, such as Denmark's hourly solar net metering and Italy's Scambio sul Posto regulations featuring specific capacity limits. The Netherlands introduced net metering as an incentive but contemplates a gradual phase-out. India's state-specific net metering regulations offer flexibility and subsidies, while Sri Lanka advocates for free net metering. Pakistan, since 2015, has instituted distributed generation and net metering regulations with specific requirements and a comprehensive procedure. Among the selected countries, the USA, Italy, Denmark, and the Netherlands have a significantly higher share of electricity generation from renewable sources, whereas India, Sri Lanka, and Pakistan provide a context more akin to Bangladesh. Therefore, the nuanced and evolving approaches to net metering in different global contexts provide valuable lessons for Bangladesh to accelerate renewable electricity generation by scaling up solar-based net metering systems.

Section III: Research Approach, Methodology and Data

This research report utilized publicly available secondary data and information collected using key informant interviews (KIIs). A comprehensive examination of a diverse range of papers, journal publications, and national policy documents was conducted to facilitate the development of both descriptive and cost-benefit analyses. The review included a thorough assessment of key national policy documents such as the Mujib Climate Prosperity Plan (MCPS) up to 2030 (GoB, 2021), Power Sector Analysis 2030 based on MCPS (IDCOL, 2021), Draft National Solar Energy Roadmap (2021-2041) (SREDA, 2020), Energy Efficiency and Conservation Master Plan up to 2030 (SREDA and MPERM, 2015), Power System Master Plan (PSMP) 2016 (MPERM, 2016), Private Sector Power Generation Policy (PSPGP) (Ministry of Energy and Mineral Resources, 2004), Renewable Energy Policy (REP) (MPERM, 2008), Net Metering Guidelines (NEG) – 2018 (SREDA and MPERM, 2018), and the 8th Five Year Plan of Bangladesh from July 2020 to June 2025 (GED, 2020). The descriptive analysis conducted to assess the present state of solar-based net metering systems primarily relies on a dataset compiled from publicly available information on the SREDA website. Furthermore, the report includes cost-benefit analyses related to the implementation of net metering-based solar systems in industrial premises, drawing insights from KIIs and information gathered from the websites of companies that have adopted NMS.

Methodology and Data: Cost-Benefit Analysis

Cost-benefit analyses are used in this study to determine the NPV and payback period of installing solar system under net metering scheme at the industrial level in Bangladesh. In this regard, the four investment arrangements listed below are used to calculate NPV and payback time.

Investment Arrangement A: Investment made by the owner of an industrial firm to satisfy a 1 MW energy demand at a debt-to-equity ratio of 70% to 30%.

Investment Arrangement B: Investment made by the owner of an industrial firm to satisfy a 1 MW energy demand at a debt-to-equity ratio of 50% to 50%.

Investment Arrangement C: Investment made by the owner of an industrial firm to satisfy a 1 MW energy demand at a debt-to-equity ratio of 30% to 70%.

Investment Arrangement D: Investment made by the owner of an industrial firm to satisfy a 1 MW energy demand at 100% equity.

For the following two loan schedules: (i) term loan and (ii) support from Bangladesh Bank's refinancing scheme, NPV and payback time are calculated in accordance with investment arrangements A, B, and C.

$$\textit{Weighted Average Cost of Capital (WACC)} = \%\ \textit{of Debt Share} * \%\ \textit{of cost of Debt} + (1 - \%\ \textit{of debt share}) * (\%\ \textit{of expected return on equity}) \text{ ---------------------- } (1)$$

$$\%\ \textit{of expected return on equity} = \left[\left(1 + \frac{\textit{Real Growth Rate}}{100}\right) * \left(1 + \frac{\textit{Inflation Rate}}{100}\right) - 1\right] * 100 \text{ -------- } (2)$$

By using equation (1) and (2) – weighted average cost of capital (WACC) is computed under abovementioned investment arrangements. WACC is calculated for term loans at 12.23% if debt is 30%, 12.16% if debt is 50%, and 12.10% if debt is 70%. In addition, WACC decreased to 10.73% for debt levels of 30%, 9.66% for debt levels of 50%, and 8.60% for debt levels of 70% if the investor could use BB refinancing support. In contrast, when an investment is made at 100% equity, WACC is highest (12.32%) (Table 1).

Table 1: Computed values of WACC under different investment arrangements

Weighted Average Capital Cost	Investment Arrangement
	Under Term Loan
WACC (with 30% debt)	12.23%
WACC (with 50% debt)	12.16%
WACC (with 70% debt)	12.10%
	Support from BB Refinancing Schemes
WACC (with 30% debt)	10.73%
WACC (with 50% debt)	9.66%
WACC (with 70% debt)	8.60%
	Self-Investment
WACC (with 0% debt)	12.32%

Source: Authors Calculation

For calculating WACC, the average inflation rate over the prior five years (6.97%) was taken into consideration (FY2018-FY2023). In addition, a 6% real growth rate (real discount rate) is predicated in accordance to Kabir et al., 2023. We found that the current capital cost for installing a 1 MW solar system is close to USD 0.80 million after interacting with a number companies who have installed NMS between 2021 and 2023. And, the average yield of electricity is 1422 KWh from per KW solar system installed. However, during estimation we considered 10 percent less efficiency in yield rate – which is 1280 KWh. The flat electricity charge for large industries is BDT 9.78/KWh in 2023 (BPDB, 2023). According to Bangladesh Energy Regulatory Commission (BERC), in March 2010, average per KWh electricity price was BDT 3.81. In this period, annual compound growth rate in electricity price is calculated to be 7.5%. Although higher electricity price rise was anticipated in planned documents like PSMP 2016, the estimation was conducted based on the sustained historical compounded growth rate. Moreover, annual regular operating costs are estimated to be 0.25 percent of the initial capital cost. In addition, it is expected that servicing and maintenance costs will be incurred by 2 percent in every five years interval (for 3 times in 20 years of solar system lifetime). Furthermore, the rate of reduction in solar panel efficiency is estimated to be 0 percent for the first five years, 10 percent from years five to ten, 20 percent from years ten to fifteen, and 30 percent from years fifteen to twenty (Table 2).

Table 2: Parameters used for computing NPV and payback time

Parameters/Conditions	Units
Initial Capital Investment	0.8 million USD/1 MW Solar System Installation
Flat Electricity Charge for large industries from March 2023	BDT 9.78/KWh
Electricity Price growth	7.5% per annum
Exchange Rate	120 BDT/USD
Average energy yield	1280 (KWh/KW)
Inflation Rate	6.97%
Real Growth Rate	6.00%
Regular Operating Cost	0.25% of initial capital cost per year
Servicing and Maintenance Cost	2 % of initial Capital cost in every five (05) years interval

Rate of Decline in Solar Panel Efficiency	
First 5 years	0%
>5 to <=10 th years	10%
>10 to <=15 th years	20%
>15 to <=20 th years	30%

For all cases, following parameters/ conditions are used to calculate the NPV and payback time using equation (3) and (4).

$$\boldsymbol{NPV = -capital\ investment + \sum_{0}^{T=20} \frac{Total\ net\ cash\ inflow\ in\ stsren\ lifespan}{(1 + nominal\ discount\ rate)^{T}}} - - - - - - - - (\mathbf{3})$$

$$\boldsymbol{Payback\ time\ (PBT) = \frac{Net\ capital\ cost}{Net\ cash\ inflow\ in\ the\ system\ lifespan}} - - - - - - - - - - - - - - (\mathbf{4})$$

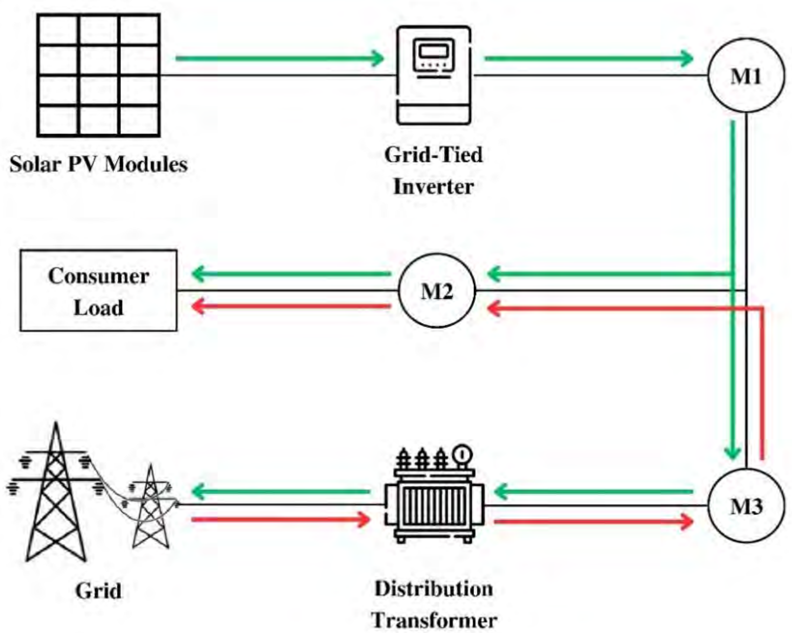
Section IV: Current Status of NEM Systems in Bangladesh

The section on the operational modality of Solar Net Energy Metering (NEM) explores the process of integrating rooftop solar systems with the power grid. Following this, the subsequent sections outline the guided NEM application procedure in Bangladesh, detailing the steps for residential, commercial, and industrial consumers. Additionally, the analysis of the current status quo sheds light on the distribution and scale of solar net metering systems across various categories.

4.1 Operational Modality of Solar Net Energy Metering

Solar Net Energy Metering, also known as Solar Net Metering, serves as a policy mechanism empowering prosumers to integrate their rooftop solar systems with the power distribution grid. Prosumers utilize solar PV panels to fulfill their building's energy needs, with the utility grid acting as a backup power source. The DC energy generated by the solar panels undergoes conversion into AC supply through a grid-tied inverter (Bedi et al., 2016). In this process, electricity flows bidirectionally through a specialized meter, or net meter, recording consumption and generation. When a prosumer consumes power from the grid, the meter registers forward movement, while it registers backward movement when surplus electricity is fed back to the grid (Figure 1).

Figure 1: Schematic Solar Net Metering Framework



Source: Net Metering Guidelines (2018); **Note:** M1, M2, and M3 represent the Solar Accounting Meter, Self-Consumption Meter, and Net Meter, respectively. However, M1 and M2 are optional for CAPEX model but mandatory for OPEX model.

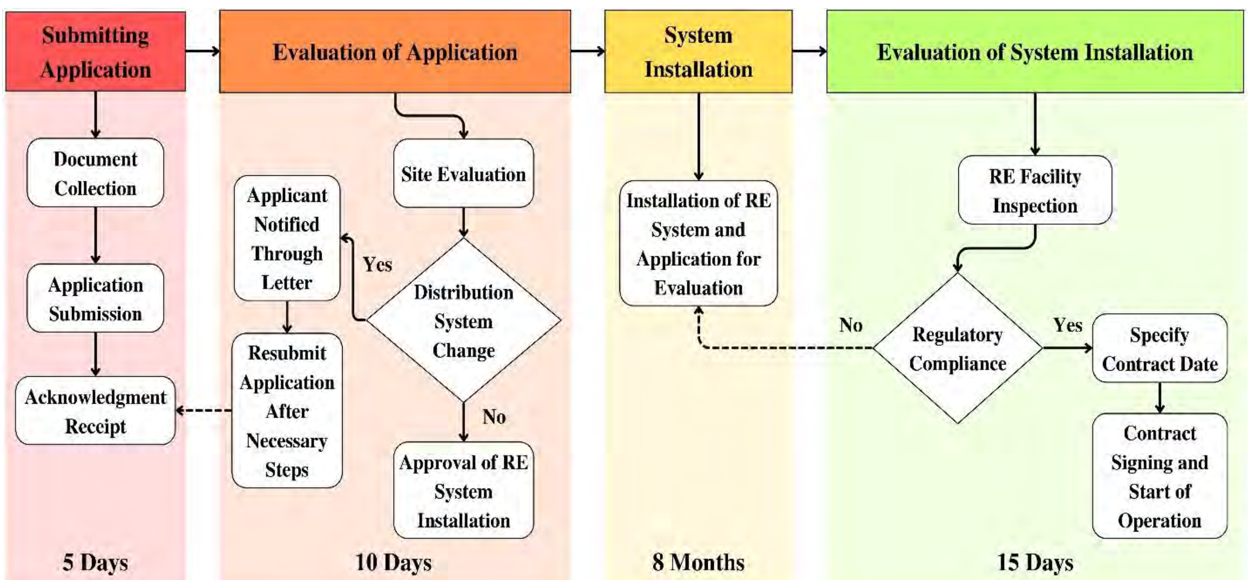
The net meter calculates the units consumed from the utility and records energy transfers (Poullikkas et al., 2013). This system allows prosumers to manage the amount of surplus electricity from their rooftop solar system transmitted to the grid after meeting their own consumption needs. Given that excess energy is directed to the grid, there is no need for energy storage expenses. According to the Net Metering Guidelines

(2018) in Bangladesh, the prosumer's bill is determined based on the net meter's records, calculated by subtracting the energy supplied to the grid from the accumulated energy consumed from the grid over a specified billing period. Figure 2 visually represents a typical solar net metering framework, illustrating the distribution of renewable energy generated by solar PV modules.

4.2 Guided NEM Application Procedure in Bangladesh

The solar net metering process in Bangladesh follows the guidelines specified in the Net Metering Guidelines – 2018, issued by the Ministry of Power, Energy, and Mineral Resources. As per these guidelines, eligible NEM consumers fall into three main categories: domestic or residential consumers, commercial consumers, and industrial consumers. Figure 3 provides an overview of the NEM application procedure in Bangladesh for all three types of NEM consumers. The complete process encompasses four primary phases and typically takes approximately nine months for full implementation (Figure 2).

Figure 2: NEM Application Procedure in Bangladesh



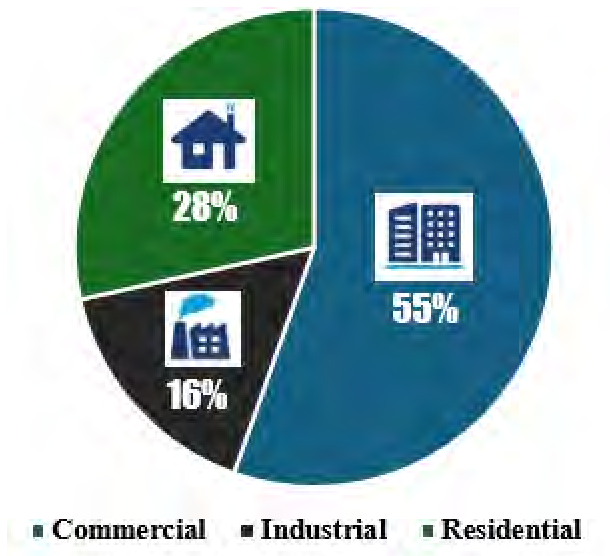
Source: Author's development from Net Metering Guidelines (2018)

To initiate the application procedure, the eligible consumer obtains the application form and NEM checklist from the respective distribution utility's office or website. Upon receiving the completed application and necessary documents, the utility issues and acknowledgment receipt. Subsequently, both the applicant and the utility establish an agreement on a comprehensive workplan, starting with an evaluation of the premises, interconnection point, and distribution system. If any adjustments to the distribution system are required, along with associated costs, the utility notifies the applicant through a formal letter. The NEM applicant bears all expenses related to any modifications to the distribution system, as outlined in the guidelines. Upon the successful completion of all necessary steps by the applicant, the utility grants NEM approval within 10 working days. Following this, the applicant must accomplish all tasks related to installing the RE system and complete the NEM system checklist within 8 months, with support from the utility. Typically, consumers either hire a third-party company or utilize their own workforce for system installation. Once the installation concludes, the applicant submits the filled NEM checklist to the utility, requesting verification of the RE system standards. The utility completes all required formalities, ensuring compliance with guidelines for system components and interconnection parameters, within a maximum of 15 working days. If the standards are not met, the utility notifies the applicant within this timeframe. Finally, upon the applicant's successful adherence to necessary steps and standards, the utility signs the NEM contract, and the system commences operation.

4.3 Current Status Quo by NEM Installation by Building Type

Since 2018 till 2023, a total 2015 solar net metering systems are installed. From the complied dataset, very sorting the very nature of building type three types of building can be classified e.g., residential, commercial, and industrial where solar net metering systems are installed. Among the all the systems installed, 55% are installed in commercial buildings followed by 28% in residential buildings and rest 16% are in industrial buildings (Figure 3).

Figure 3: Percentage distribution of installed NEMs by building types



Source: Author's development from the database of SREDA, 2023

The data reveals insights into the distribution and scale of solar net metering systems across different categories. In the commercial sector, comprising 1,117 systems, the average capacity per installation is 9.86 KWp, with capacities ranging from a minimum of 0.45 KWp to a maximum of 200.00 KWp. The industrial category, encompassing 324 systems, stands out with significantly larger installations, boasting an average capacity of 222.65 KWp (Figure 4).

Table 3: Average Capacity by Category

Category	Number of Systems	Average Capacity Per System (in KWp)	Minimum Capacity (in KWp)	Maximum Capacity (in KWp)
Commercial	1,117	9.86	0.45	200.00
Industrial	324	222.65	1.00	8738.00
Residential	574	3.77	0.19	50.00
All	2,015	42.34	0.19	8738.00

Source: Author's calculation from the database of SREDA, 2023

The range within the industrial sector is extensive, spanning from a minimum capacity of 1.00 KWp to an impressive maximum of 8,738.00 KWp. Residential solar net metering systems, totaling 574, exhibit a comparatively smaller average capacity of 3.77 KWp, suitable for individual households. The range within the residential category varies from a minimum of 0.19 KWp to a maximum of 50.00 KWp. When considering all categories collectively, involving a total of 2,015 systems, the overall average capacity per system is 42.34 KWp (Figure 3). The dataset illustrates a diverse landscape of solar net metering installations, accommodating varying scales of energy generation across commercial, industrial, and residential sectors.

4.4 Trend of NEM Installation by Building Type in the period of 2018-2023

The data provides a comprehensive overview of the evolving landscape of residential, commercial, and industrial solar net metering systems over the years. In the residential sector, the number of systems has gradually increased from 18 in 2018 to 67 in 2023. Despite fluctuations, the average capacity per residential system has shown consistency, ranging from 3.18 KWp in 2019 to 5.48 KWp in 2023. The commercial sector witnessed a substantial rise in the number of systems, reaching 139 in 2022, and then slightly decreasing to 104 in 2023. The capacity per commercial system has consistently been higher than residential systems, with notable peaks in 2018 (12.50 KWp) and 2023 (13.36 KWp). Industrial solar net metering systems, while fewer in number, exhibit remarkable capacity figures, especially in 2021 (767.47 KWp) and 2022 (411.21 KWp), reflecting larger-scale installations. Overall, the data underscores a growing adoption of solar net metering across all sectors, with each sector demonstrating distinctive trends in system numbers and capacity per system (Figure 4).

Table 4: Trend of NEM Installation by Building Type

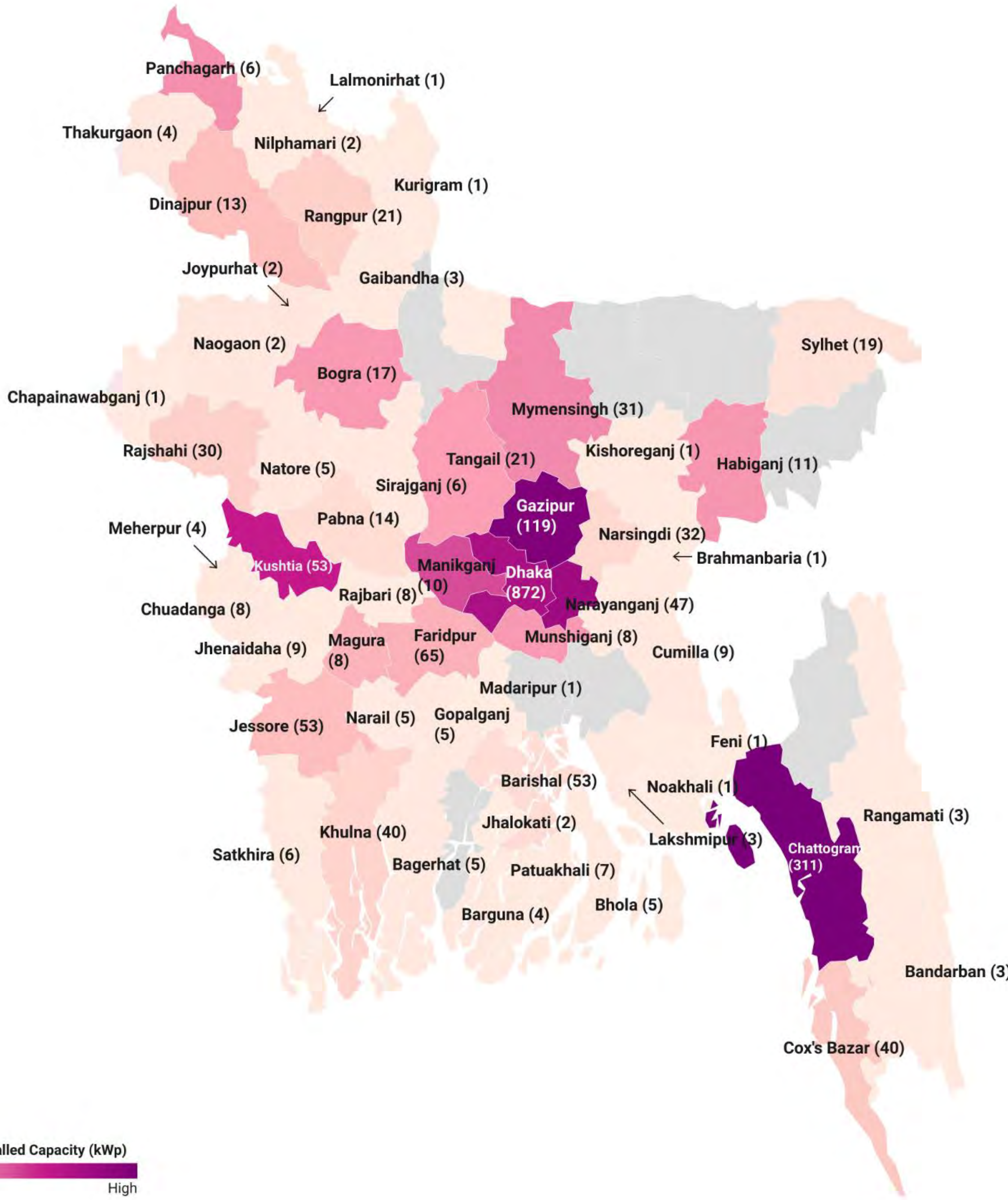
	Residential		Commercial		Industrial	
Year	# of Systems	Capacity Per System (in KWp)	# of Systems	Capacity Per System (in KWp)	# of Systems	Capacity Per System (in KWp)
2018	18	5.69	37	12.50	33	365.28
2019	229	3.18	344	9.96	144	105.90
2020	123	3.79	302	8.91	52	26.61
2021	61	3.64	191	8.03	23	767.47
2022	76	3.70	139	10.84	44	411.21
2023	67	5.48	104	13.36	28	275.26
Total	574	3.77	1,117	9.86	324	222.65

Source: Author's calculation from the database of SREDA, 2023

4.5 Spatial Variation in NEM Installation by Districts

Since the introduction of NEM in 2018, its implementation has expanded to nearly all districts of Bangladesh over the span of five years. This indicates that NEM adoption is feasible across the country, provided that buildings are equipped with the necessary features to accommodate solar installations. The distribution of installed solar net meter systems across various districts highlights notable variations. Dhaka District stands out with the highest number of installations, accounting for 43.32% of the total systems, followed by Chittagong at 15.45%. Notably, Gazipur, Faridpur, and Barishal each contribute 6%, 3.2%, and 2.6%, respectively (Figure 4). Industrial areas such as Chittagong, Narayanganj, and Gazipur witness a substantial number of NEM installations, reflecting the emphasis on solar adoption in industrial buildings. Conversely, districts like Brahmanbaria, Chapainawabganj, and Natore exhibit minimal installations, each comprising less than 0.1% of the total. This data underscores the uneven distribution of solar energy infrastructure across Bangladesh, indicating potential areas for targeted interventions and further development initiatives.

Figure 4: Solar NEM Projects and its Energy Generation Capacity by Districts

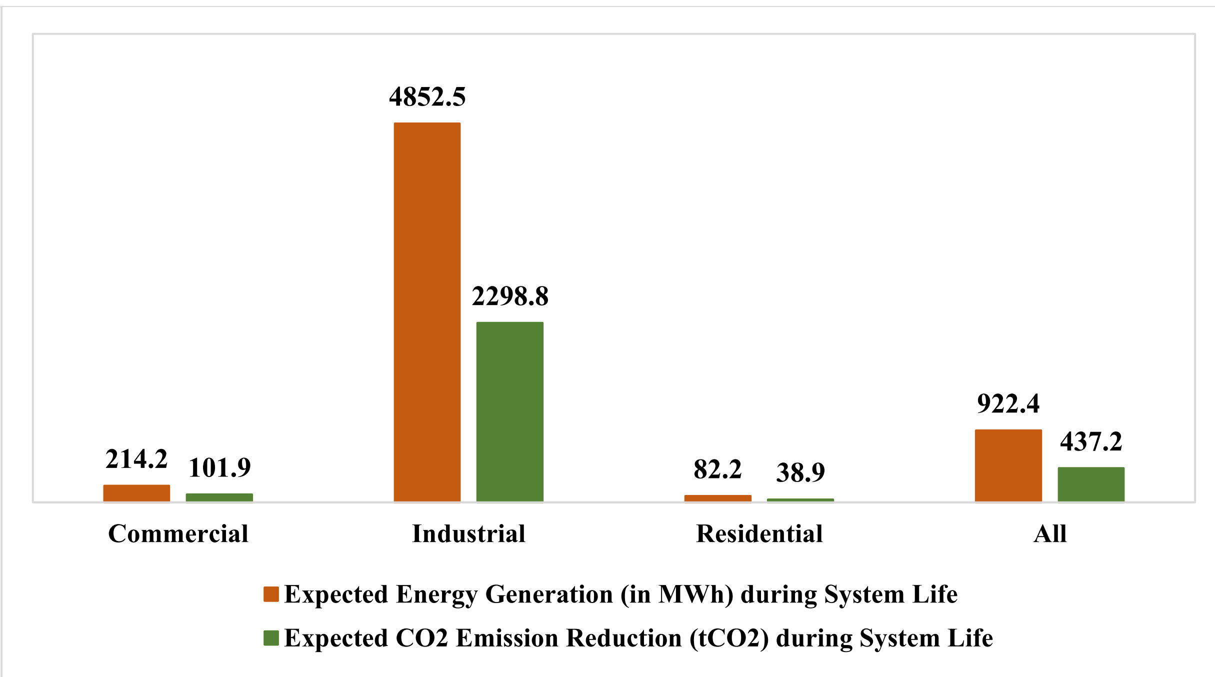


Source: Author's Compilation from National Database of Renewable Energy, SREDA, as of December, 2023.

4.6 Expected Impact from Existing Installed NEMs over its System Life

The data illustrates the expected energy generation and CO2 emission reduction over the lifespan of solar systems categorized by type and their respective numbers of installations. Industrial installations are anticipated to generate the highest proportion of energy at 4852.5 MWh, accounting for 52.6% of the total energy generation, and they are expected to contribute to 52.6% of the total CO2 emission reduction, amounting to 2298.8 tons, reflecting their larger scale and impact. Commercial systems, while comprising 55.5% of the total number of installations at 1117 systems, are projected to generate 214.2 MWh of energy, constituting 23.2% of the total energy generation, and reduce CO2 emissions by 101.9 tons, representing 23.3% of the total emission reduction. Residential installations, although the most numerous with 574 systems, are expected to generate 82.2 MWh of energy, contributing 8.9% to the total energy generation, and reduce CO2 emissions by 38.9 tons, comprising 8.9% of the total emission reduction. Overall, these solar systems, totaling 2015 installations, are projected to generate 922.4 MWh of energy and reduce CO2 emissions by 437.2 tons over their lifespans, highlighting the significant environmental benefits of solar adoption across diverse sectors (Figure 5).

Figure 5: Expected Energy Generation Capacity (in MWh) and CO2 Emission Reduction during System Life

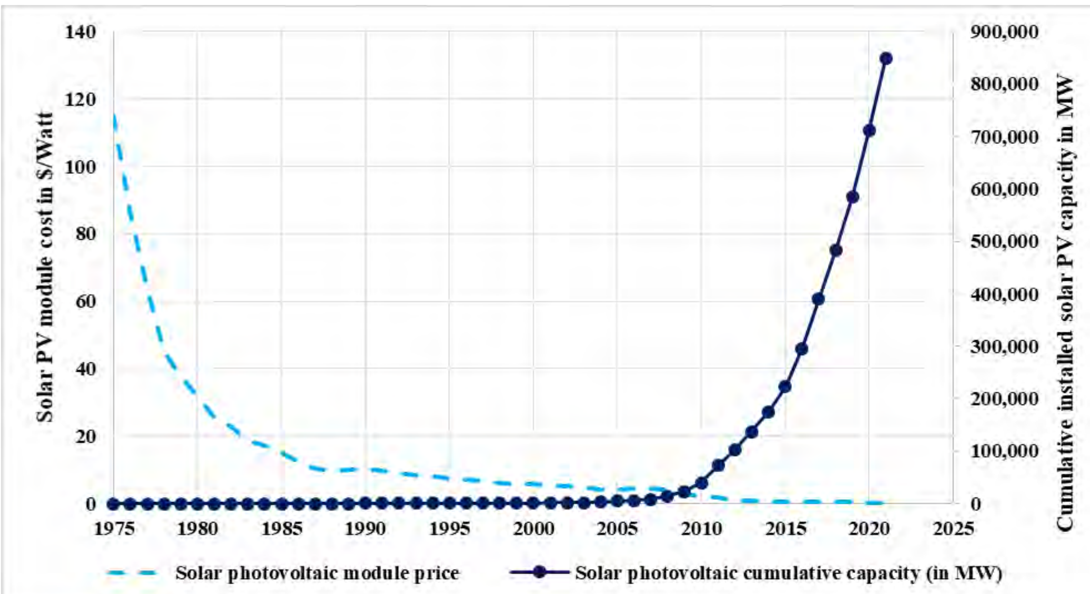


Source: Author’s calculation from the database of SREDA, 2023

Section V: Result of Cost-Benefit Analysis Installing NEM in industrial premises

Solar energy conversion has seen widespread adoption for power and heat generation since 2007-2008, as illustrated in Figure 6. According to the International Energy Agency (IEA), solar system installations are projected to fulfill approximately 45 percent of the global energy demand by 2050. Notably, solar thermal applications in industrial settings have gained significant traction, finding use across various industries. Moreover, industrial buildings have increasingly integrated solar electricity to power essential equipment such as lights, pumps, engines, fans, freezers, and water heaters. Over the years, the cost of solar panels has witnessed a substantial decline; from less than $1 per watt in 2012 to now over $0.26 per watt. This downward trend in prices is anticipated to persist in the future, further incentivizing the adoption of solar energy technologies.

Figure 6: Trend of solar panel (photovoltaic) prices vs. cumulative capacity (1975-2021)

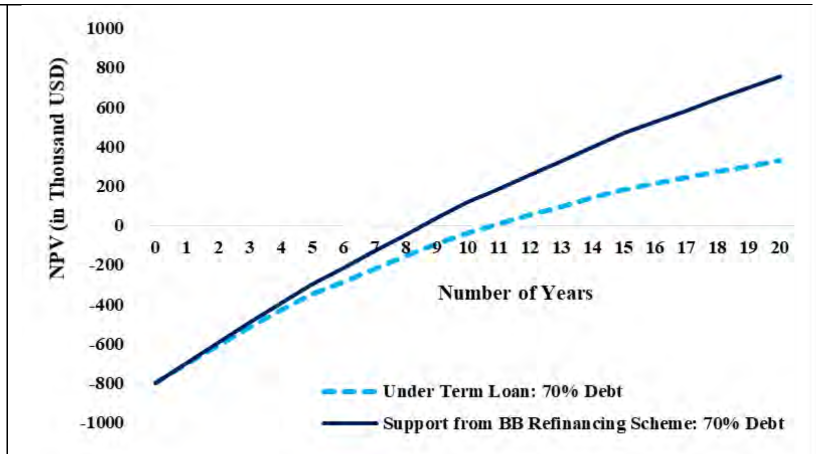


Source: Nemet (2009); Farmer & Lafond (2016); International Renewable Energy Agency (IRENA); Note: Data is expressed in constant 2021 US$ per Watt.

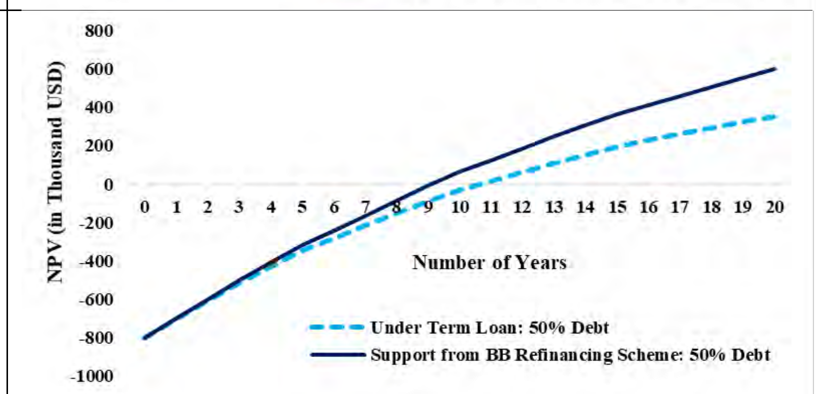
Since the adoption of net metering policy in 2018 businesses alongside their commercial space are also expressing higher interest in setting solar PV in the industrial premises and rooftops to attain higher energy efficiency in the production process as well as to reduce cost. Although PV installation was first slow at the industrial level, and later COVID-19 further slowed the process, a sizable number of businesses have now started to install NMS in their factor level after recognizing the financial benefit of it. In this particular study, it is found that installing PV at the industrial level under the NMS scheme yielded positive NPV on investment for all four investment scenarios using the cost benefit technique.

Figure 7: Results of NPV analyses to install 1 MW Solar NEM at Industrial Premises

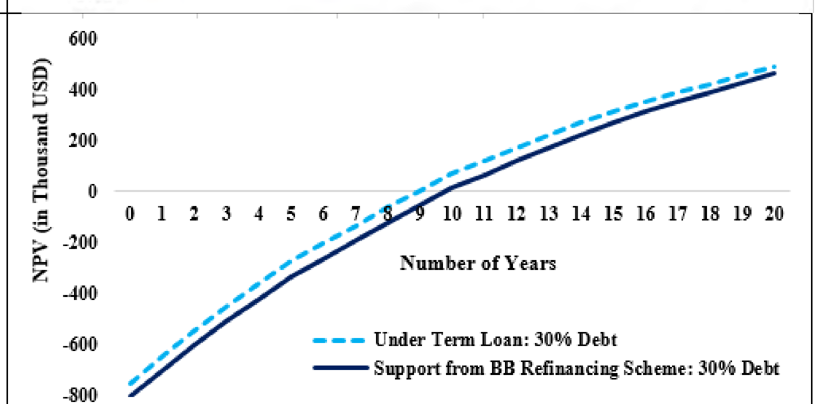
Investment Arrangement
A



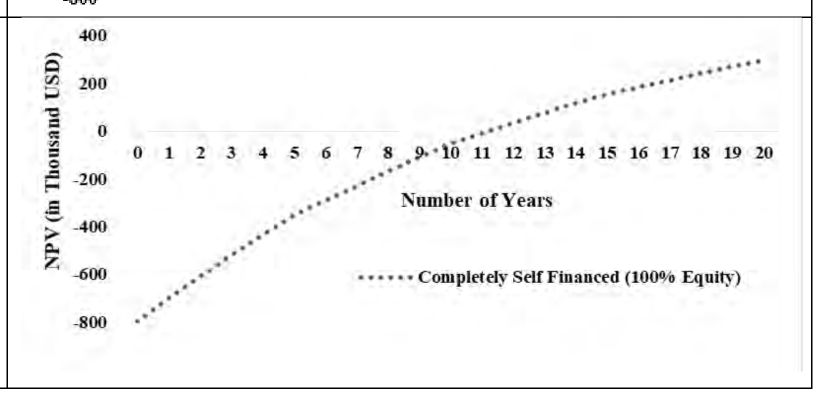
Investment Arrangement
B



Investment Arrangement
C



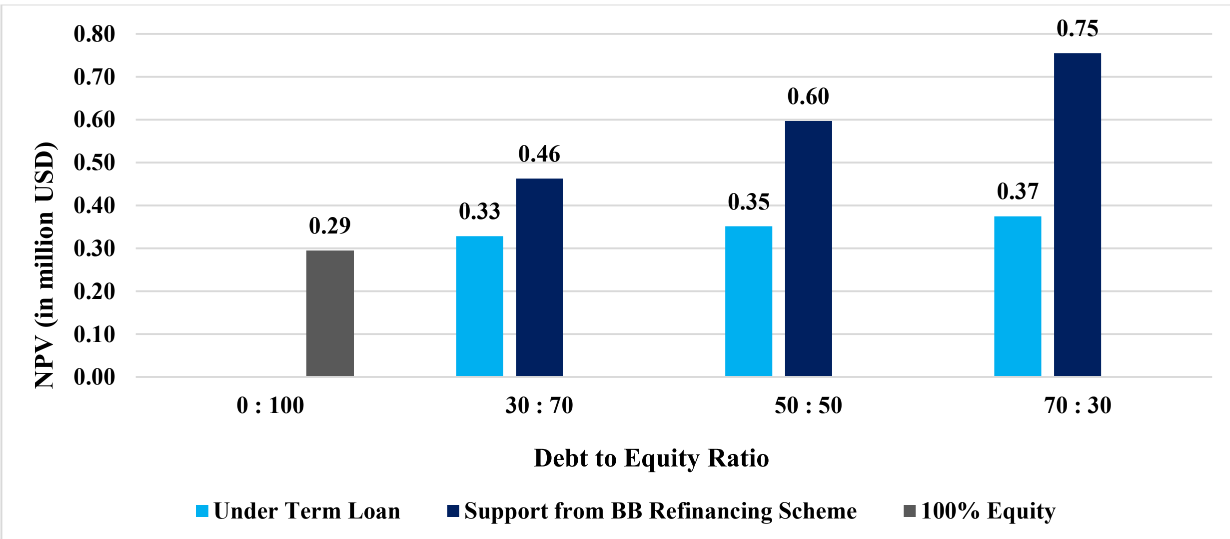
Investment Arrangement
D



Source: Authors Calculation

The results of the cost-benefit analysis for the industrial set up show that investment arrangement A (to install a 1 MW NMS in the factor/industrial premise or rooftop) yields a positive NPV equivalent to USD 0.75 million and a payback time of 8.5 years when debt is received under BB's existing refinancing facility (Figure 7 and Figure 8). In contrast, when debt is received as a regular term loan from a bank or non-bank financial institution, under investment arrangement A, it yields a positive NPV equivalent to USD 0.37 million and the payback time is found to be 10.5 years (Figure 7, Figure 8 and Figure 9). Under the BB's refinancing facility loanable funds are accessible at 7 percent interest rate while under regular term loan it is 12 percent.

Figure 8: Net present value by types of investment arrangement

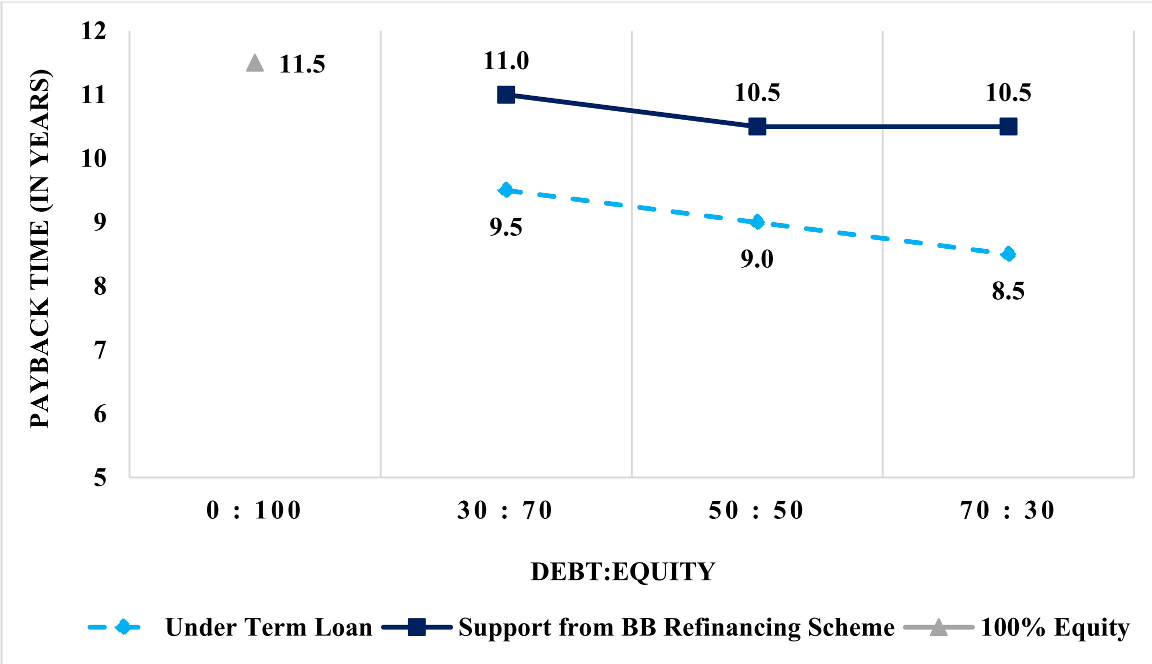


Source: Authors Calculation

Similarly, investment arrangement B yields a positive NPV equivalent to USD 0.60 million and a payback time of 9 years when debt is received under BB's existing refinancing facility. In contrast, when debt is received as a regular term loan from a bank or non-bank financial institution, under investment arrangement B, it yields a positive NPV equivalent to USD 0.35 million and the payback time is found to be 10.5 years.

At the same time, investment arrangement C yields a positive NPV equivalent to USD 0.46 million and a payback time of 9.5 years when debt is received under BB's existing refinancing facility. In contrast, when debt is received as a regular term loan from a bank or non-bank financial institution, under investment arrangement C, it yields a positive NPV equivalent to USD 0.33 million and the payback time is found to be 11 years (Figure 7 and Figure 8). Investment arrangement D yields a positive NPV equivalent to USD 0.29 million and a payback time of 11.5 years when investment is made using 100 percent equity by the company itself (Figure 9).

Figure 9: Payback time (in years) by investment arrangement



Source: Authors Calculation

It demonstrates that investment scenario A, in which the investor obtained 70 percent of the debt through BB's refinancing program, is the most beneficial from promoting NMS installation. Even in investment scenario A, an investor who secures BB's refinancing scheme will see a net return that is nearly twice as high as that of a standard term loan. In addition, the cost of capital payback period is one year earlier than the term loan arrangement. It emphasizes how critical financing is to motivating investors to put money into sustainable businesses and to increase efficiency in the process.

Section VI: Potential of scaling up solar NEMs in EPZs of Bangladesh

Currently, eight EPZs operate under Bangladesh Export Processing Zone Authority (BEPZA), encompassing a total of 2,518 industrial plots over 2,404 acres. Adamjee EPZ, spanning 293 acres with 273 industry plots, is a significant economic zone in Siddhirganj, Bangladesh, focusing on export-oriented production since its inception in 2006. Chattogram EPZ, the largest among them with 453 acres and 501 industry plots, holds historical importance as Bangladesh's first EPZ established in 1983 (Table 5). Each EPZ, from Cumilla to Ishwardi and Karnaphuli to Mongla, contributes uniquely to the nation's industrial landscape. However, the Korean Export Processing Zone (KEPZ), the country's largest and sole private EPZ, stands out as a pioneer in environmental sustainability, with transformative initiatives and an ambitious solar power generation project. The initiative to establish a 40 MW solar PV capacity, culminating in an Independent Power Plant (IPP), underscores KEPZ's dedication to renewable energy adoption. The first phase, involving a 16 MW system, was inaugurated in June 2021, followed by a 4.3 MW system in the second phase by the end of 2021. Furthermore, plans for an additional 20 MW system, to be established as an Independent Power Plant (IPP), await government approval, marking a significant step towards reducing reliance on non-renewable energy sources. Analyzing KEPZ's progress in NEM-based solar systems presents a compelling argument for policymakers to reconsider and advocate for NEMs in all EPZs. Collaboration between BEPZA and SREDA in promoting NEMs across EPZs not only enhances energy efficiency for existing businesses but also aligns with Bangladesh's commitment to renewable energy-based electricity generation, as outlined in its NDC. Embracing NEMs within existing and upcoming EPZs emerges as a strategic imperative, offering a pathway towards sustainable industrial development and fulfilling national environmental obligations. The subsequent segment presents simulation results advocating for BPEZA to permit NEM systems within existing EPZs and forthcoming EZs.

Table 5: Simulated Results on the Potential of scaling up solar NEMs in EPZs

EPZ	Zone area (acres)	No. of industry plots	20% of Area Under NEM		30% of Area Under NEM	
			Installed Capacity (MW)	Electricity Generation (MWh) per year	Installed Capacity (MW)	Electricity Generation (MWh) per year
Adamjee	293	273	27	39,432	41	59,148
Chattogram	453	501	42	61,045	63	91,567
Cumilla	267	243	25	36,042	37	54,063
Dhaka	356	451	33	48,003	49	72,004
Ishwardi	309	324	29	41,636	43	62,453
Karnaphuli	209	258	19	28,172	29	42,258
Mongla	303	278	28	40,827	42	61,241
Uttara	214	190	20	28,792	30	43,188
Total	2404	2518	222	323,948	333	485,922

Source: Authors Calculation

In an optimal location with abundant sunlight, each square meter would typically receive approximately one kilowatt (kW) of sun light, resulting in a maximum insolation of around 9.3 kW. With a 17% efficiency in PV systems, it's projected that an average insolation capacity of 1580W per day can be achieved. Therefore, if there are 3.5 hours of daily bright sunlight for 280 days in a year, the expected electricity generation would be nearly 1320 kWh per year per square meter of solar PV.

The simulation results demonstrate the potential impact of implementing NEM in EPZs across various regions in Bangladesh. This analysis highlights the significant role these zones could play in facilitating the national grid's installed capacity and electricity generation. Across the eight EPZs, a total of 2518 industrial plots span an area of 2404 acres. Even if only 20% to 30% of these areas, including rooftops and open spaces, were used to solar PV-based net metering systems (NMS), an additional capacity ranging from 222 MW to 333 MW could be added to the national grid from renewable energy sources (Table 5). Extrapolating from these statistics, the potential electricity generation from NMS at the industrial level could range from 323,948 to 485,922 megawatt-hours (MWh) if EPZs were connected to NMS. This analysis underscores the importance of implementing renewable energy solutions of solar PV systems in connection to NEM, within industrial zones to enhance energy sustainability and reduce reliance on non-renewable sources.

Section VII: Conclusion

This study has fulfilled its primary aim of assessing the current status of solar-based net metering systems in Bangladesh and exploring their potential in advancing towards renewable energy. This was achieved by conducting a cost-benefit analysis of implementing net-meter based solar systems in industrial settings and investigating the scalability of such installations in Export Processing Zones (EPZs).

The results indicate a significant uptake of solar technology across residential, commercial, and industrial sectors since 2018, with 2015 installations documented by 2023. The data demonstrates the varied distribution of solar net metering systems, with commercial and industrial buildings leading in capacity, reflecting diverse energy generation needs.

Furthermore, the cost-benefit analysis offered valuable insights into the financial viability of investing in net-meter based solar systems in industrial premises. Four investment arrangements were examined, highlighting the importance of financing mechanisms such as BB's refinancing facility in promoting sustainable business practices and improving overall efficiency.

Moreover, the study underscores the potential for expanding net solar system installations in EPZs, emphasizing their critical role in enhancing energy sustainability and reducing reliance on non-renewable sources. Simulation results suggest that utilizing portions of industrial plot areas for solar PV-based Net Metering Systems (NMS) could significantly increase renewable energy capacity in the national grid.

Additionally, the study advocates for promoting Net Energy Metering (NEM) systems, particularly targeting industrial clusters. Effective coordination between BPEZA and SREDA is essential for accelerating NEM implementation in these clusters, including upcoming economic zones. While current NEM installations primarily focus on buildings with three-phase connections, further research and pilot initiatives are recommended to improve technical efficiency.

Furthermore, recognizing the substantial potential in rural areas, SREDA should expand efforts to penetrate sub-urban and rural regions, leveraging their abundant rooftop spaces and south-facing houses. Exploring community-level operational and capital expenditure setups could enhance financial feasibility. By implementing these recommendations, stakeholders can expedite the deployment of solar-based net metering systems, contributing to a more sustainable energy landscape in Bangladesh.

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