COST-BENEFIT ANALYSIS OF NET-METERED ROOFTOP SOLAR IN BANGLADESH AND ITS RELATION WITH TILTING ANGLE

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Abstract - Solar energy is very much potential among all renewable energy (RE) sources in Bangladesh and rooftop solar can play a vital role to achieve the national RE targets as land scarcity is the main problem to promote utility-scale solar plants. The government of Bangladesh published "Net metering guidelines-2018" to promote rooftop solar in the country. A clear business model is essential to promote rooftop solar under the net metering scheme. Also, due to the COVID-19 situation, the business model of rooftop solar is affected by price hikes and high inflation. This paper analyzes the business case with financial analysis in the current situation with a real case study. The financial parameters LCOE, IRR, NPV, and Payback period have been calculated separately for 'self-finance' and 'with finance' modalities. After that, the relation of the business model with the tilting angle of the plane of the array has been analyzed. The business model of net-metered rooftop solar will be in a good position if the retail electricity tariff increases significantly.

Keywords: Rooftop solar in Bangladesh, Net energy metering, Net metering business models, Financial analysis with tilting angle, LCOE, IRR, NPV, Payback period

1. INTRODUCTION

Renewable energy, environmentally friendly, is the energy of the next generation for the world [1]. The country Bangladesh is also trying to go to clean energy development considering its resources and technological advancements [2], [3]. Rooftop solar can play a significant role to achieve this goal and the government published a policy titled "Net metering guidelines-2018" to promote rooftop solar in Bangladesh [4]. Net metering is a policy incentive by the government on which unconsumed energy from renewable energy systems is fed into the distribution network and is utilized by the nearby consumers of the same distribution network [5]. After a month, the exported electricity will be adjusted with the imported electricity and the consumer will pay the utility for net electricity consumption (import-export), that is why the term "net metering" is coming [6]. Till today, 1765 number of net-metered rooftop solar with a cumulative capacity of 52.81 MW have been installed in the country[7], which is very less according to the expectation. The Solar Home System (SHS), which was a revolution in Bangladesh to support access to electricity has more than 6 million installations [8]. SHS increased energy access through SHS in rural Bangladesh contributes to rural development [9]. Net metered rooftop solar is going to be another revolution in Bangladesh by following SHS.

Some research was trying to demonstrate the drivers of solar energy development in a country like Bangladesh but not addressed the whole scenario [10]. Land scarcity is the main problem to promote ground-mounted utility-scale solar power plants whereas rooftop solar can play a significant role under the net-metering scheme [4]. Also, for the ground-mounted utility-scale solar power plants, the authors of [11] criticized that sustainable development concerns not only economic or environmental sustainability but also the social sustainability of marginal, poor people [12].

Research shows that the average efficiency of Floating Solar Photovoltaic (FPV) is 11% higher than that of land-based Photovoltaic (PV) plants [13]. FSPV not only utilize the duty-free water surface, but it has enormous advantages including low Levelized cost of electricity compared to terrestrial land-based PV plants, high energy efficiency due to the cooling effect from water evaporation, fewer obstacles to block sunshine, prevents water evaporation, land and water conservation, limits algae growth by blocking penetration of sunlight [12]. The economic prospects of a rooftop solar project on a commercial building have been reviewed in paper [14], but the present situation is more favourable for this consumer class as well as some other consumer classes.

This paper analyzes the rooftop solar scheme of Bangladesh along with the insights of 'Net metering guidelines-2018'. The following issues are addressed to do this.

a) Procedure and important issues of net metering rooftop solar in Bangladesh have been described;
b) Investment requirement has been analyzed by a recent real case study project;
c) Financial analysis has been conducted for a different types of consumer classes;
d) The relation of financial parameters with tilting angle has been analyzed.

Those studies are very scarce from the country Bangladesh perspective. There are six chapters, where the first (1) chapter describes the need for the research, objectives, and approach. The second (2) chapter, described the research methodology. The basic principle of the net-metered rooftop solar under 'Net metering guidelines-2018' has been discussed first in this chapter and then the procedure of the study has been discussed. The third (3) chapter describes the important issues that are related to the business model of net-metered rooftop solar. A case study to find out the business model of rooftop solar has been discussed in the fourth (4) chapter. The fifth (5) chapter represents the results and discussion of the study according to the research methodology. In the last chapter six (6), the research findings, recommendations, and opportunities of the work were discussed.

2. METHODOLOGY

The government of Bangladesh published the "Net metering guidelines-2018" for the promotion of rooftop solar in the country whereas net metering can be done from all renewable energy sources. The electricity consumers, who have sanctioned load and rooftop area, can apply to their electricity distribution utilities to avail of the net metering facility. There are two models, Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). Under the CAPEX model; installation, operation, and maintenance will be done by the consumer whereas it will be done by a third party in the OPEX model. The consumer will buy electricity produced from the rooftop solar under an OPEX agreement with that third party in the OPEX model. A general block diagram of net-metered rooftop solar is shown below in Fig. **1**.

In Fig. **1**, the Point of Common Coupling (PCC) is the point where the connection of the solar system is connected with the existing utility connection within the consumer premises and generally it is a Low Tension (LT) busbar of that building. Solar modules are connected with grid-tied inverters and all cumulative Alternating Current (AC) output terminals of inverters are connected to the PCC through an energy meter (EM-2), which is known as a solar generation meter. The left side of the PCC is the consumer's load where EM-3 is the measuring energy meter. The right side of the PCC is the supply from the utility side and EM-1 is the utility energy meter that will be bidirectional for net metering consumers. The electricity, generated from the rooftop solar, will be used to the consumer's load on a priority basis and surplus electricity will be exported to the distribution grid which will be counted by the EM-1. The monthly export unit will be adjusted with the import unit, if the export is higher then it will be preserved as a credit to be adjusted in the next month and it will continue up to the end of the fiscal year, 30th June.

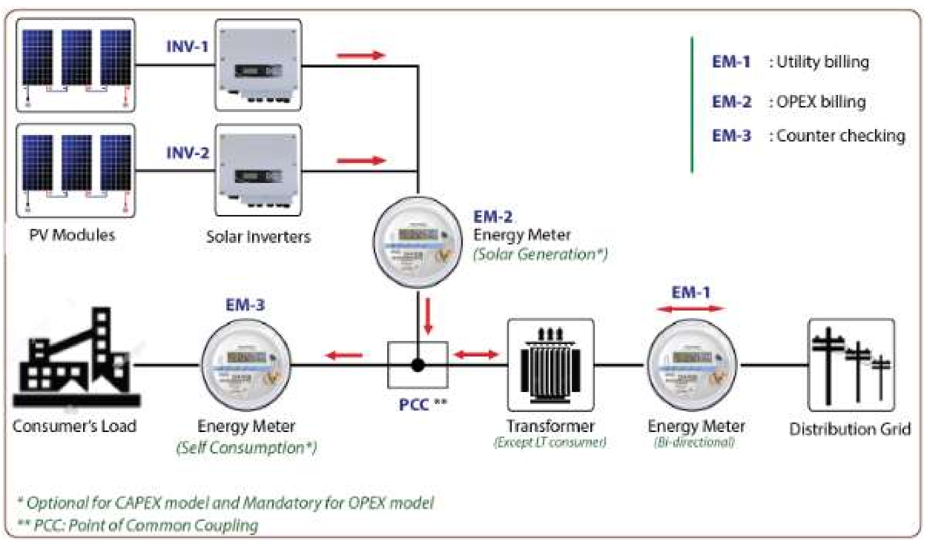

Fig. 1. General block diagram of a net-metered consumer

For the promotion of net-metered rooftop solar, a business model is essential. The business model of any solar project depends on some factors where solar irradiation of selected location and tilting angle of the plane of arrays are important. In this study, a recently installed rooftop solar site will be taken as a case study for analysis of the business model. The power generation relation with respect to the tilting angle of the plane of the arrays of the case study site will be analyzed by the global solar atlas developed by SOLARGIS, ESMAP and the World Bank Group. Finally, parameters of the business models, not limited to the Net Present Value (NPV), Payback Period (PBP), Internal Rate of Return (IRR), and Levelized Cost of Electricity (LCOE); will be analyzed for different tilting angles.

3. IMPORTANT ISSUES RELATED TO THE NEM BUSINESS MODELS

Several factors are related to the business models of rooftop solar in Bangladesh. Some of those are described below.

3.1. Solar resources in Bangladesh

The solar radiation, received on the solar module, contributes to generating electrical energy from the solar system. The output of the solar system is completely dependent on the input solar irradiance. Global Horizontal Irradiation (GHI), Direct Normal Irradiation (DNI), Diffuse Horizontal Irradiation (DHI), Photovoltaic Power Output (PVOUT), etc. are the common form to understand the solar irradiation status of a place where GHI is very common for general understanding. A GHI resource map of Bangladesh developed by Solargis is given below in Fig. **2**.

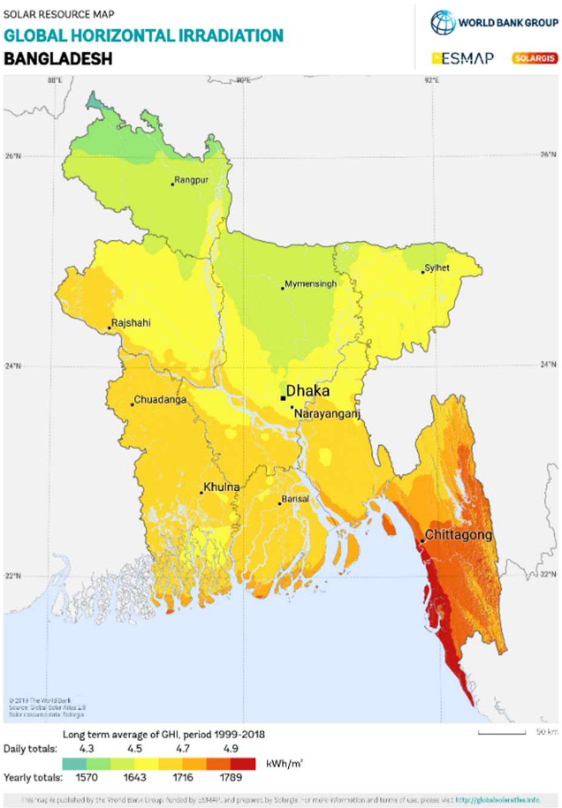

Fig. 2. GHI Solar resource map of Bangladesh [15]

Fig. **2** is a solar resource map represented by the colours where deep green represents the lowest irradiation and deep red represents the highest irradiation. It is a representation of the long-term average of GHI for the period 1999 to 2018. The colour scale represents the daily total or yearly total irradiance in kWh/m^2. According to the figure, the Chittagong division has the highest solar irradiation (more than 1800 kWh/m^2/year) in Bangladesh and Khulna, Barishal and Rajshahi divisions have moderate solar irradiation. Similarly, the Rangpur division has the lowest solar irradiation (around 1500 kWh/m^2/year) status. Therefore, the maximum to minimum solar irradiation variation is less than 20%.

3.2 Solar irradiance and its components

Solar irradiance has main two components, direct irradiance and diffuse irradiance. Diffuse irradiance comes from the reflection of the cloud, ground, nearest building or similar obstacles, etc. The combination of direct irradiance and diffuse irradiance is called Global Irradiance. These components are shown in **Fig. 3** below.

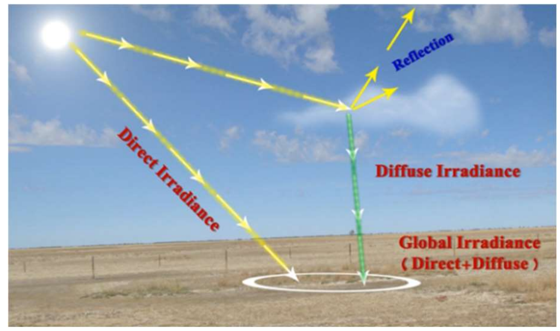

Fig. 3. Components of Solar irradiance

3.3. Module mounting structures and their effects

The solar module can be mounted in different ways. It may be classified as fixed mounting structures and tracking-based mounting structures. Tracking-based mounting structures may be classified as 1-axis tracking and 2-axis tracking whereas one axis is related to daily tracking and another axis is related to seasonal tracking. Tracking-based mounting structures are not popular for rooftop solar projects in Bangladesh but they may be suitable for solar irrigation and other projects. The optimum tilting angle, which normally closes the latitude angle of that location, is the angle where the solar module gives the maximum energy output during a whole year. However, fixed mounting structures with optimum tilting angles and rail/clamp-based solar module mounting on a sloped roof with a roof's tilting angle are popular now. The incidence of global irradiance on the roof-aligned solar module is slightly lower than the irradiance on the module mounted at the optimum tilting angle because it loses some parts of direct irradiance. Although the variation of diffuse irradiance does not differ that much. This tilting angle deviation from the optimum tilting angle is related to the power generation of the solar system as well as the financial parameters like NPV, Payback period, and IRR. An example of clamp-based Rooftop solar with a roof's tilting angle is shown in Fig. **4** below.

Fig. 4. KEPZ rooftop solar, Anowara, Chittagong, Bangladesh

Fig. **4** is a part of the largest net-metered rooftop solar project in Bangladesh (14 MWp) till now, located at the Korean Export Processing Zone (KEPZ), Anowara, Chittagong. The solar modules of the same tilting angle are connected to the inverter by making arrays. Although annual electricity production from this system will be less than an equivalent capacity system with optimum tilting angle, the cost of the mounting structure and its other effects (design complexity on shaded roof, weight of mounting structure, wind effect, etc.) have been reduced.

3.4. Bangladesh standards of solar accessories

To ensure the quality of solar modules and inverters, some Bangladesh Standards (BDS) are mandatory for the net metering rooftop solar program. Bangladesh Standards and Testing Institution (BSTI) adopted those standards as BDS from the standards of the International Electrotechnical Commission (IEC) without any deviation. The following standards, mentioned in table 1, are mandatory for net metering rooftop solar programs according to the “Net metering guidelines-2018” [16].

Table 1: Bangladesh standards of solar module and inverter

SL.	Equipment	Bangladesh Standards of Solar Appliances
1.	Solar Module/Panel	BDS IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval BDS IEC 61730-1:2019 Photovoltaic (pv) module safety qualification part 1: Requirements for construction BDS IEC 61730-2:2019 Photovoltaic (pv) module safety qualification part 2: Requirements for testing
2.	Inverter	BDS IEC 62109-1 Safety of power converters for use in photovoltaic power systems - Part 1: General requirements BDS IEC 62109-2 Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters BDS IEC 61727:2020 Photovoltaic (PV) systems - Characteristics of the utility interface BDS IEC 62116:2020 Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures

3.5. Installation quality of rooftop solar system

Quality design, installation, and inspection are also important besides the quality of solar modules and inverters. DIN VDE0100 (General Requirements), VDE 0100-712 and VDE-AR-N 4105 (Special Requirements), IEC 62446 (Inspection) and VDE 0100-520 (Cable and Power line selection) are some standards that are mentioned in the net metering guideline as promotional basis. The DIN VDE 0100-100 is a german standard which is equivalent to the IEC 60364-1:2005. Similarly DIN VDE 0100-712 is equivalent to the IEC 60364-7-712:2017 and DIN VDE 0100-520 is equivalent to the IEC 60364-5-52:2009.

4. A CASE STUDY TO FIND OUT THE BUSINESS MODEL

A 448 kWp Net metered rooftop solar system has been installed and commissioned on 20 July 2022 by consumer Debunear Limited (Ltd.), Ghorat, Yearpur, Savar Upazila, Dhaka. Debunear Ltd. is a consumer of Dhaka Pallibidyut Somittee (PBS)-1 with a consumer number 14-1310[17]. The latitude and longitude of the site are 23.94329 and 90.30394. This solar project was initiated as a CAPEX model of ‘Net metering guidelines-2018’.

Fig. 5. A drone view of 448kWp rooftop solar case study project

Dual Cell Monocrystalline Passivated Emitter and Rear Contact (PERC) solar module of Canadian Solar and inverter of SMA Solar Technology AG were used in this project. The solar modules (830 pcs), inverters (8 pcs, 50kW each) and data manager were imported directly by Debunear Limited and the other items, installation, testing, and commissioning were done by a reputed Engineering Procurement Construction (EPC) company of Bangladesh. The cost of solar modules and inverters was $ 153,315 excluding VAT and Tax. The supply and service value of local EPC was BDT 4,968,259 including all Value Added Tax (VAT) and Tax.

Considering VAT, Tax, the USD conversion rate of the current position, etc.; the initial investment cost of the solar system should not be more than 60,000 BDT/kWp. This value will be used for business case analysis.

According to the information of Global Solar Atlas [18], the Global horizontal irradiation (GHI) of this site is 1642.7 kWh/m^2/year. Similarly, Direct normal irradiation (DNI), Diffuse horizontal irradiation (DHI), and Global tilted irradiation at an optimum angle (GTI_{opta}) are 989.9 kWh/m^2/year, 947.0 kWh/m^2/year and 1753.7 kWh/m^2/year whereas 23°/180° are the optimum tilting angle and azimuth angle. According to the SOLARGIS Specific photovoltaic power output (PVOUT) calculation, 1390.4 kWh/kWp/year is the expected annual electricity production from this site. The calculation SOLARGIS PVOUT takes into account solar radiation, air temperature, and terrain, to simulate the energy conversion and losses in the PV modules and other components of a PV power plant. In the simulation, losses due to dirt and soiling were estimated to be 3.5%. The cumulative effect of other conversion losses (inter-row shading, mismatch, inverters, cables, transformer, etc.) is assumed to be 7.5%. The power plant availability is considered to be 100%. The Horizon and sunpath diagram of that site is given below in Fig. **6**.

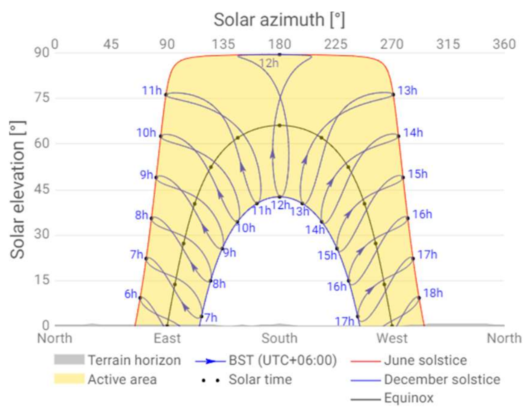

Fig. 6. Horizon and Sunpath diagram of 23.94329 and 90.30394

According to the detailed analysis of SOLARGIS PVOUT for a 448 kWp rooftop solar system on the case study site with 23°/180° angles, around 605 MWh of electricity will be produced in the first year[18]. If we consider a 13% less PVOUT of 1390.4 kWh/kWp/year due to the grid outage, maintenance shutdown and other issues, the PVOUT value will be around 1210 kWh/kWp/year.

5. RESULTS AND DISCUSSION

An approximate 8-10 m^2 rooftop area is needed for each kWp rooftop solar system with an optimum tilting angle in Bangladesh and it depends on the design of the solar system and the efficiency of the solar PV module. They have sufficient rooftop area on that building. The total capacity of the solar module is 448kWp whereas the total capacity of the inverter is 400kW. Therefore, DC:AC ratio is 1.12. The 60,000 BDT/kWp is considered as initial investment cost with self-finance. Large maintenance and replacement cost has been considered as 25% of the initial investment cost in the 11th year. 5% of the annual return has been considered for regular maintenance and cleaning purposes. Insurance cost depends on the insurance items (i.e., general insurance, fire, etc.) and it is applicable only for the price of insurance items (Solar module, Inverter, etc.). Generally, it may be considered as 0.8% on the insurance components which is equivalent to 0.6% of the total initial investment cost of such a rooftop solar project.

The PVOUT value of 1200 kWh/kWp/year will be used initial power generation capacity of the solar system for model development. According to the tariff order 2020, the consumer class of Debunear Limited is 11kV industrial peak-offpeak where the retail electricity tariff is 7.7 BDT/kWh and 5% VAT will be added with it. A minimum tariff increment has been considered where the current retail electricity tariff will prevail for up to one year and it will increase by 0.30 BDT/kWh after every 2 years. The bulk tariff of this utility is 5.3925 BDT/kWh according to the tariff order 2022. A 7% discount factor has been considered for this analysis for inflation which was between 5% to 6% before the COVID-19 crisis.

The total initial investment cost of a 448 kWp solar system will be 26.88 million BDT (60 thousand BDT/kWp × 448 kWp). Financing costs will be added for the CAPEX projects other than self-finance. IDCOL model has been chosen to understand the financing cost that will be added to this model. 80% of the initial investment cost will be provided as debt with a 6% interest rate, 10 years tenor, quarterly repayment and one year grace period for principal only. Therefore, 80% of the initial investment cost, 21.5 million BDT will be the loan amount and the cost of financing is described in table 2 given below.

Table 2: Financing values to find out the cost of money

Year	Remaining Principal (BDT)	Principal Pay (BDT)	6% Interest (BDT)	Present Value Factor (PVF)	Interest in Present Value (BDT)
Y1	**21,500,000**	0	1,290,000	0.94340	1,216,981
Y2	21,500,000	2,388,889	1,290,000	0.89000	1,148,095
Y3	19,111,111	2,388,889	1,146,667	0.83962	962,763
Y4	16,722,222	2,388,889	1,003,333	0.79209	794,734
Y5	14,333,333	2,388,889	860,000	0.74726	642,642
Y6	11,944,444	2,388,889	716,667	0.70496	505,222
Y7	9,555,556	2,388,889	573,333	0.66506	381,299
Y8	7,166,667	2,388,889	430,000	0.62741	269,787
Y9	4,777,778	2,388,889	286,667	0.59190	169,678
Y10	2,388,889	2,388,889	143,333	0.55839	80,037
END	**0**	**21,500,000**	**7,740,000**		**6,171,239**

It is calculated from table 2 that 7.74 million BDT is the total cost of financing in future values and 6.171239 million BDT is the total cost of financing in present value. Based on the all of identified information, the investment and return analysis have been conducted and mentioned in Table 3.

Table 3: Investment and return analysis to make a business model

Year	Present Value Factor (PVF)	Investment Cost (BDT)	Investment Cost in Present Value	Maintenance Cost (BDT)	Maintenance Cost in Present Value	Insurance Cost (BDT)	Insurance Cost in Present Value	Electricity Generation (kWh)	Tariff (BDT/kWh)	Tariff + 5% VAT	Annual Savings (BDT)	Annual Savings in Present Value
1	**2**	**3**	**4=2×3**	**5=12×5 %**	**6=2×5**	**7**	**8=2×7**	**9**	**10**	**11**	**12=9×11**	**13=2*12**
Y0	1.00000	26,880,000	26,880,000									
Y1	0.93458	0	0	215,152	201,076	161,280	150,729	532,224	7.70	8.09	4,303,031	4,021,524
Y2	0.87344	0	0	220,373	192,482	161,280	140,868	524,698	8.00	8.40	4,407,460	3,849,646
Y3	0.81630	0	0	218,567	178,415	161,280	131,653	520,397	8.00	8.40	4,371,333	3,568,310
Y4	0.76290	0	0	224,889	171,567	161,280	123,040	516,096	8.30	8.72	4,497,777	3,431,332
Y5	0.71299	0	0	223,015	159,006	161,280	114,990	511,795	8.30	8.72	4,460,295	3,180,129
Y6	0.66634	0	0	229,134	152,681	161,280	107,468	507,494	8.60	9.03	4,582,674	3,053,629
Y7	0.62275	0	0	227,192	141,484	161,280	100,437	503,194	8.60	9.03	4,543,838	2,829,674
Y8	0.58201	0	0	233,108	135,671	161,280	93,866	498,893	8.90	9.35	4,662,153	2,713,416
Y9	0.54393	0	0	231,098	125,702	161,280	87,726	494,592	8.90	9.35	4,621,962	2,514,041
Y10	0.50835	0	0	236,811	120,383	161,280	81,987	490,291	9.20	9.66	4,736,213	2,407,651
Y11	0.47509	6,720,000	3,192,624	234,733	111,520	161,280	76,623	485,990	9.20	9.66	4,694,667	2,230,403
Y12	0.44401	0	0	240,243	106,671	161,280	71,610	481,690	9.50	9.98	4,804,854	2,133,413
Y13	0.41496	0	0	238,098	98,802	161,280	66,925	477,389	9.50	9.98	4,761,953	1,976,041
Y14	0.38782	0	0	243,404	94,396	161,280	62,547	473,088	9.80	10.29	4,868,076	1,887,924
Y15	0.36245	0	0	241,191	87,419	161,280	58,455	468,787	9.80	10.29	4,823,820	1,748,374
Y16	0.33873	0	0	246,294	83,428	161,280	54,631	464,486	10.10	10.61	4,925,878	1,668,565
Y17	0.31657	0	0	244,013	77,248	161,280	51,057	460,186	10.10	10.61	4,880,268	1,544,968
Y18	0.29586	0	0	248,913	73,644	161,280	47,717	455,885	10.40	10.92	4,978,262	1,472,888
Y19	0.27651	0	0	246,565	68,177	161,280	44,595	451,584	10.40	10.92	4,931,297	1,363,545
Y20	0.25842	0	0	251,261	64,931	161,280	41,678	447,283	10.70	11.24	5,025,227	1,298,614
Total		**33,600,000**	**30,072,624**	**4,694,052**	**2,444,704**	**3,225,600**	**1,708,603**	**9,766,042**			**93,881,040**	**48,894,087**

20 years has been considered as commercial project life although it may run a few years more. Column 1 indicates the number of years, column 2 represents the present value factor considering the 7% discount factor. Columns 3 and 4 are major investment costs in future values and present values respectively. 5% of annual savings mentioned in column 12 will be used as a regular maintenance cost. It is mentioned in columns 5 and 6 in future form and present form respectively. Similarly, insurance costs are mentioned in columns 7 and 8 respectively. During the commissioning time, the power generation degradation will be considered zero (efficiency 100% from a degradation perspective), and the system will provide 1200 kWh/kWp/year if continue with zero degradation in that year. Practically it is not possible and a 0.8% degradation factor is considered in this study. Therefore, the first-year degradation will be 2% and the rest of the year's annual degradation will be 0.8%. Considering this, the first year's average PVOUT will be 1188 kWh/kWp/year and the 20th year's average PVOUT will be 998 kWh/kWp/year. Therefore, considering these aspects, the annual electricity generation of a 448 kWp solar system has been calculated and mentioned in column 9. Columns 10 and 11 represent the retail electricity tariff in BDT without VAT and including 5% VAT. Column 12 is the value of the annual savings in the present form which is the multiplication between columns 9 and 11. Column 13 is the present form of annual savings. The last row of the table represents the summation of all year's values. The total expenditures in different items are calculated for self-finance mode and with finance mode and placed in Table 4. Finally, the financial terms LCOE, NPV, IRR, and PBP has been projected for 11kV industrial offpeak tariff consumer.

Table 4: Total expenditure summary and financial terms

SL	Cost Items	Self Finance		With Finance	
		Future Value (BDT)	Present Value (BDT)	Future Value (BDT)	Present Value (BDT)
1	Total investment cost	33,600,000	30,072,624	33,600,000	30,072,624
2	Total maintenance cost	4,694,052	2,444,704	4,694,052	2,444,704
3	Total Insurance cost	3,225,600	1,708,603	3,225,600	1,708,603
4	Total financing cost			7,740,000	6,171,239
	Total cost	41,519,652	34,225,931	49,259,652	40,397,170
	Total Electricity Generation in kWh	9,766,042	9,766,042	9,766,042	9,766,042
	Levelized Cost of Electricity (LCOE)	4.25 BDT/kWh	**3.50 BDT/kWh**	5.04 BDT/kWh	**4.14 BDT/kWh**
	Net Present Value (NPV)	14,668,157 BDT			8,496,918 BDT
	Internal Rate of Return (IRR)	13.41%			11.13%
	Payback Period (PBP)	11.22 Years			14.36 Years

It was observed from that the LCOE of 'self-finance' is 3.50 BDT/kWh and the LCOE of 'with finance' is 4.14 BDT/kWh. Similarly, NPVs are 14,668,157 BDT and 8,496,918; IRRs are 13.41% and 11.13%; Payback periods are 11.22 years and 14.36 years respectively. These figures are for this consumer class and the values of other consumer classes will be different. Some of those are given below in Table 5.

Table 5: Consumer class-wise financial analysis of net-metered rooftop solar

	Voltage Level	**11 kV Medium Tension [5MW≥SL>50kW]**				**33 kV High Tension [30MW≥SL>5MW]**			**0.4 kV Low Tension (LT) [up to 80kW]**			
Consumer class	**Financial Parameters**	**Commercial and Office**	**Industrial**	**General**	**Residential**	**Commercial and Office**	**Industrial**	**General**	**Commercial and Office**	**Industrial**	**Charging ST**	**Educational, Health**
Tariff	Retail Electricity Offpeak Tariff	8.21	7.7	7.61	7.56	8.12	7.61	7.57	9.27	7.68	6.88	6.02
	Retail Electricity Offpeak Tariff with 5% VAT	**8.62**	**8.09**	**7.99**	**7.94**	**8.53**	**7.99**	**7.95**	**9.73**	**8.06**	**7.22**	**6.32**
Self Finance	**Levelized Cost of Electricity (LCOE),** BDT/kWh	**3.52**	**3.50**	**3.50**	**3.50**	**3.52**	**3.50**	**3.50**	**3.55**	**3.50**	**3.48**	**3.46**
	Net Present Value (NPV), BDT	17,351,111	14,668,157	14,194,694	13,931,659	16,877,649	14,194,694	13,984,266				
	Internal Rate of Return (IRR)	14.52%	13.41%	13.22%	13.11%	14.33%	13.22%	13.13%	16.79%	13.37%	11.60%	9.64%
	Payback Period (PBP) in years	10.39	11.22	11.39	11.49	10.53	11.39	11.47	9.04	11.25	12.89	15.25
With Finance	**Levelized Cost of Electricity (LCOE),** BDT/kWh	**4.15**	**4.14**	**4.13**	**4.13**	**4.15**	**4.13**	**4.13**	**4.18**	**4.14**	**4.11**	
	Net Present Value (NPV), BDT	11,179,872	8,496,918	8,023,455	7,760,420	10,706,410	8,023,455	7,813,027				
	Internal Rate of Return (IRR)	12.37%	11.13%	10.91%	10.78%	12.16%	10.91%	10.81%	14.89%	11.08%	9.07%	
	Payback Period (PBP) in years	13.19	14.36	14.6	14.74	13.4	14.6	14.71	11.31	14.41	16.77	

Note: *SL = Sanctioned load; LT consumers are not allowed for 448kWp rooftop solar, hence NPV is blank*

In Table 5, three broad consumer classes are addressed those are 11 kV Medium Tension (MT), 33 kV High Tension (HT) and 0.4 kV Low Tension (LT). 3-4 separate consumer classes under each broad class were addressed for financial analysis. The financial analysis was divided into two items, one is the 'self-finance' mode and another is the 'with finance' mode. As there is a ceiling limit of a sanctioned load of LT consumers, they are not capable to install the rooftop solar system beyond its sanctioned load capacity. Here, the annual electricity consumption of consumers is considered higher than the annual solar electricity generation. Hence, some of the parts of Table 5 are missing for LT consumers. Under self-finance and with finance mode, four financial parameters, LCOE, IRR, PBP, and NPV have been calculated through the net metering calculator of SREDA[19]. It shows that all financial parameters depend on the retail electricity tariff of that consumer and the highest tariff class gives the best financial results. A comparative position of MT consumers is shown below in Fig. **7**.

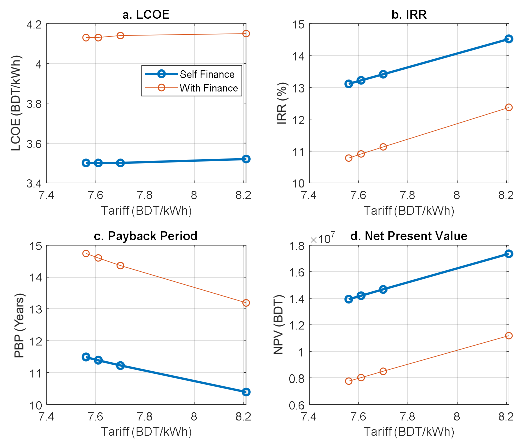

Fig. 7: A comparative financial analysis among MT consumer classes

In Fig. **7**(a), LCOE is almost equivalent for each consumer class because it is not dependent on the tariff but rather depends on the expenditures and electricity generation during the project life. The small change was observed because of the regular maintenance cost related to the 5% of annual savings which is a part of the expenditure. Similarly in Fig. **7**(b), IRR is increasing with the increase of tariff; in Fig. **7**(c), the Payback period is decreasing with the increase of tariff and in Fig. **7**(d), NPV is increasing with the increase of tariff.

The financial parameters are depended on the electricity generation amount from the solar system and it depends on the solar irradiation incident on the solar modules. Tilt angle is one of the factors on which incident solar irradiation will change and hence the amount of electricity generation from the system will be changed. In this study, SOLARGIS PVOUT data was collected from a global solar atlas site for different tilt angles and a 13% less scenario was also developed that will be used for financing model calculation [18]. The tilt angle considered from the south facing (180^0 azimuth) in the case study location, from -30^0 to 60^0. Those data are presented in Fig. **8**.

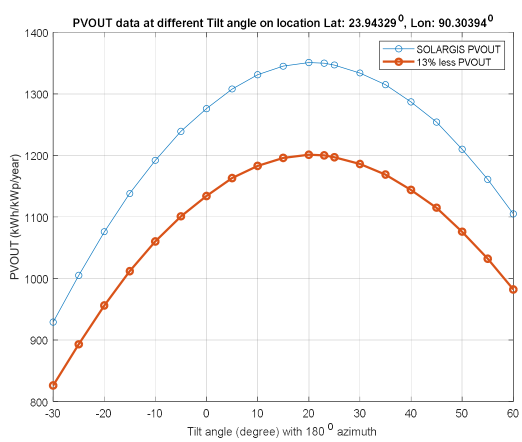

Fig. 8: Solar photovoltaic power output (PVOUT) at different tilt angles at the case study site location

It is observed from Fig. **8** that the PVOUT value is increasing and reached its maximum position between 20 to 24-degree tilt angle and then again decreasing. The maximum PVOUT position is called as optimum tilting angle. The difference in PVOUT between the optimum tilt angle position and zero degrees tilt angle position is less than 75 kWh/kWp/year. Similarly, the difference between the optimum tilt angle position and the 15^0 tilt angle position is less than 5 kWh/kWp/year and the difference between the optimum tilt angle position and the 10^0 tilt angle position is less than 20 kWh/kWp/year. Therefore, for a small deviation of tilt angle from the optimum tilt angle, the power generation output of the solar power plant will not be changed by a significant figure and its financial parameters will remain close. The actual scenario may differ slightly that depends on the accuracy level of solar irradiation analysis of SOLARGIS. The relations of financial parameters with tilt angle for self-finance MT industrial consumer class are shown in Fig. **9** below.

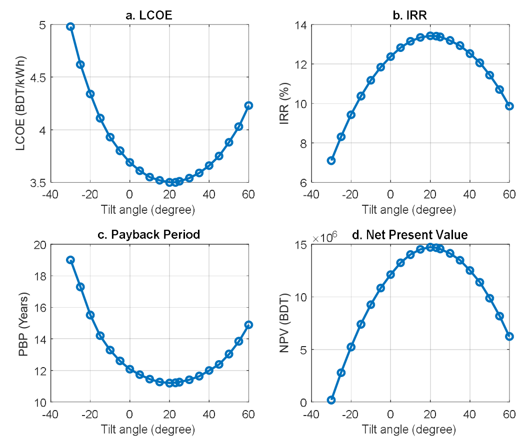

Fig. 9: Financial analysis at different tilt angles for 11kV industrial consumer

In Fig. **9** (a & c), LCOE and Payback period are minimum at the optimum tilting angle position and increasing with the deviation from the optimum tilting angle. Similarly, In Fig. **9** (b & d), IRR and NPV are maximum at the optimum tilting angle position and decrease with the deviation from the optimum tilting angle. During the project design phase, the deviation of financial parameters from the optimum tilting angle to the suitable tilting angle is needed to be considered with the other facilities to select the suitable tilting angle.

CONCLUSION

There is a clear business model for net-metered rooftop solar in Bangladesh under "Net metering guidelines-2018". The business model was more lucrative before the COVID-19 situation due to the price hike and inflation factor, which was between 5% to 6%. Now the inflation of 7% is considered to calculate the business model. For the MT industrial consumer class, the LCOE of ‘self-finance’ is 3.50 BDT/kWh and the LCOE of ‘with finance’ is 4.14 BDT/kWh. From the LCOE perspective, the projects are lucrative. But IRRs are 13.41% and

11.13%; Payback periods are 11.22 years and 14.36 years respectively for the 'self-finance' and 'with finance' modalities. Consumers may not be interested to wait for this long payback period from the 20 years of commercial project life.

As the financial parameters of the business model of net-metered rooftop solar are very much dependent on the retail electricity tariff, financial parameters will be in a good position if the retail electricity tariff will increase to a significant level compared with the regular increment. According to the analysis of tilting angle compromisation, the energy loss amount is not very much compared with other benefits. Therefore, clamp-based roof angle-aligned rooftop solar may be promoted for the shaded rooftops. Also, solar systems on flat roofs may be designed a few degrees lower than the optimum tilting angle to reduce the use of rooftop areas and take some seasonal benefits.

Overall, the current business model of net-metered rooftop solar is in a good position and it needs to be more lucrative for wider and faster promotion in Bangladesh.

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