Business Case: Solar PV Rooftop System for RMG Factory - Opex Model

Support to Safety Retrofits and Environmental Upgrades in the Bangladeshi Ready-Made Garment (RMG) Sector

Rationale for Solar Rooftop:

Renewable energy, especially solar energy, is rapidly emerging as a sustainable power source around the globe. Direct sunlight, which is free, abundant and reasonably reliable, is used to produce power with solar PV panels. To meet the increasing demand of energy in the RMG sector, solar power can be one of the most cost effective and feasible solutions. The energy sources that are currently used by the RMG sector are expected to become more expensive in the future as the government gradually adopts market-based pricing mechanisms for electricity and gas, the price of which always went up in the past. Also, considering the increasing demand, the existing reserve and supply of fossil fuels is no longer able to guarantee energy sustainability in this sector. On the other hands, brands (e.g. H&M) are focusing more on renewable energy to ensure low carbon emissions, scope 3 emissions, with the target to be of climate neutral by 2030 and climate positive by 2040 throughout their supply chains. Incorporation of rooftop solar PV systems can reduce the negative impact on productivity and machineries' life from frequent load shedding in the RMG sector. The main equipment of solar PV power systems, the solar PV panels, can be easily installed on the unused roofs, shades or empty spaces of the factory premise and requires no extra land or space. The installation of solar PV systems on the roofs or unused spaces of industry can be accommodated easily for a wide range of power generation capacities.

Advantages of Solar Rooftop Systems:

With global installed capacity of over 500 GWp and an average annual growth rate of more than 40% over last 10 years [Renewables 2019 Global Status Report, REN 21], solar PV technology has become the fastest growing power solution of the world. This is primarily due to the following noticeable benefits associated with this technology.

Direct Benefits:

Lower energy cost than conventional utilities	The cost of electricity from rooftop solar PV systems is much cheaper than the conventional grid electricity. Considering the present cost trends of solar equipment and concessionary financial facilities available in Bangladesh, the cost of electricity generated from rooftop solar PV systems can be 20~30% less when compared to the commercial tariff rates of utility electricity. This has the potential not only to reduce the average energy cost of the industry, but also bring down the overall consumption from the conventional sources of energy.

Photo: Installed rooftop Solar PV panels at the DPQSL factory building at Mater Bari, Valuka, Mymensingh.

Zero fuel cost	The solar energy that is converted by solar PV panels is clean and is available in abundance at no cost. As long as the world exists, the sun will continue to radiate its energy, which will be available for utilization. The RMG industry typically has its peak operational time during the day and the solar energy is also available at the same time.
Low maintenance	Solar PV systems generally do not require heavy maintenance as they have no moving parts. Only regular cleaning of solar PV panels is necessary. The warranty periods of the major system components are quite long, e.g., the solar panel manufacturers give 25 years of output warranty, and the warranty for gird-tied solar inverters is 5~10 years. After covering the initial installation cost of the system, no major investment is required for maintenance and repair of the solar PV systems.
No additional space requirement	For installation of an industrial rooftop solar PV system, no additional space is necessary for PV panel installation. There is no need to vacate a land or invest in buying additional lands to setup rooftop solar PV systems. Furthermore, installed panels give an extra layer of protection to the roof building.
Variety of installation options	Solar panel structures come in many varieties depending on the selected roof area & dimension. Hence, the system can be accommodated in almost any given space, and thus can utilize most of the free space available on the roof.
Net metering	After self-consumption, the excess electric energy generated by the installed solar PV system can be exported to the connected national grid. The exported amount of electricity can offset the portion of consumed electricity from the grid.

Indirect Benefits:

Low carbon emission	Solar PV based electricity has a very low carbon footprint. While producing electricity from solar energy, no Greenhouse Gas (GHG) is emitted. Thus, it offsets GHG emissions. No smoke or smog is produced. Therefore, the technology is environmentally benign.
Reduced cooling demand of the factory building	Solar PV installation on the industrial roofs reduces ambient temperature inside the shade by some extent, which further reduces the electricity required for cooling purposes.
Employment opportunity	The installation & commissioning works of a solar PV project create local jobs, and thus help develop the solar industry as an entirely new sector. Therefore, widespread implementation of solar PV systems can exert significant impact on the overall economy of the country.

OPEX Model:

The solar OPEX model is increasingly becoming popular as an operating model globally. In this model, a third-party investor, technology provider or OPEX operator (often called an energy service company (ESCO) or renewable energy service company (RESCO)) makes the capital investment for the Solar PV system installation on the factory roof. A Power Purchase Agreement (PPA) is signed between the technology provider and consumer under which the consumer agrees to purchase the generated output from the solar PV system at a certain pre-agreed tariff during the PPA tenure, and also agrees to give site access rights to the investor for operation and maintenance of the plant.

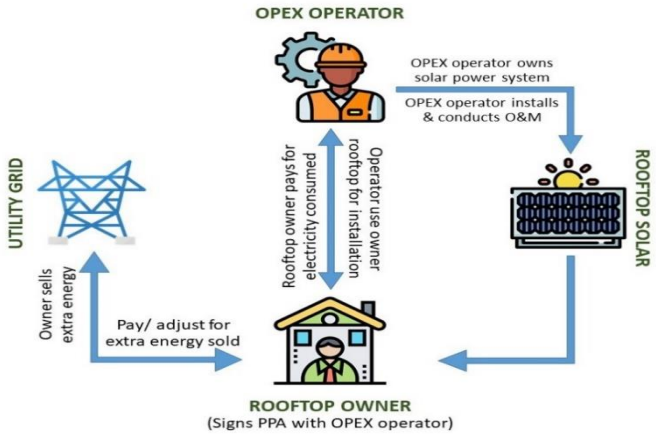


Figure: Typical OPEX model structure.

While the structure of the PPA may vary widely, the following are the common forms used in a solar OPEX model:

- BOOT (Built-Own-Operate-Transfer)
- BOO (Built-Own-Operate)

BOOT (Built-Own-Operate-Transfer):

In this model, the OPEX operator is responsible for design, installation, finance, operation and maintenance of the solar plant for a certain agreed period (the PPA tenure). The consumer usually purchases the entire generated electricity from the rooftop solar PV system during such a period at a pre-agreed tariff. Afterwards, the OPEX operator transfers the fully operational plant to the consumer (free of cost or at a certain pre-agreed price), who continues enjoying solar energy almost free of cost for the rest of system's life (only needs to bear the O&M cost and some replacement cost). The OPEX operator can be engaged for O&M of the plant under a long-term service agreement or the consumer can develop his own O&M team. Tariff charged by the OPEX operator in this model is usually less than the grid electricity tariff. From the consumer's perspective, it is important to ensure that the plant uses proven equipment so that it runs efficiently during its entire operational life.

Photo: Installed rooftop Solar PV panels at the DPQSL factory building at Mater Bari, Valuka, Mymensingh.

BOO (Built-Own-Operate):

The major difference between the BOOT and BOO models is that there is no transfer of ownership from the OPEX operator to the consumer and the operator continues owning and operating the plant throughout the plant's life. However, there can be early exit clauses in the PPA which gives the consumer the option to take over the plant at any time during the PPA tenure by paying a certain compensation amount to the operator.

For the BOO model, it is beneficial for the consumer to enter into a long term PPA (usually 20 years or for the entire operational life of the plant) to get the lowest possible tariff. Also, it is less important to worry about the quality of equipment or the services or the operation and maintenance requirement, as the consumer will only pay per kWh of electricity generation.

In both the BOOT and BOO models, tariff rates can widely vary based on a number of parameters i.e. PPA tenure, transfer price options, available financing terms from lenders, etc. In its simplest form, the tariff can be fixed for the entire PPA tenure. It can also have a fixed escalation provision (annually or after some other predefined interval). Sometimes the tariff is also linked with the utility tariff (usually a certain percentage lower than the utility tariff).

Advantages of OPEX to the RMG Industry:

- No upfront capital investment from the industry
- No additional leverage by taking a direct loan from lenders
- Guaranteed benefit, as electricity tariff from the OPEX operator is generally lower than the grid tariff
- Better accountability with stable and reliable financial forecasts which may be challenging in a CAPEX model
- No need to develop in-house technical capacity for the operation and maintenance of the solar plant, as it is not the core business activity of the RMG industry. The OPEX operator is responsible for the O&M of the plant.

Net Energy Metering Solutions:

Net Energy Metering (NEM) refers to a policy mechanism that allows prosumers [consumers of electricity who also produce electricity] to connect their renewable energy (RE) systems to the distribution grid. As a result, any excess electricity (after self-consumption) generated from renewable sources can be supplied to the distribution grid. The electricity generated in the weekly holidays or other holidays can be exported to the national grid. In exchange, the prosumer can either import an equivalent amount of electricity from the grid, or accumulate credits for net exported electricity on a monthly basis and receive the price of it by the end of the settlement period, as per the Net Metering Guidelines-2018 approved by the Government of Bangladesh. In the NEM system, electricity consumed from the grid and exported to the grid are both recorded separately.

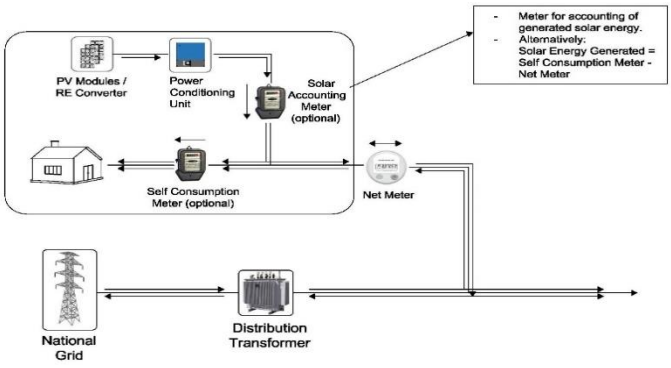


Figure: Typical Net Energy Metering Architecture.

Eligibility Criteria for becoming a Net Energy Metering Consumer:

A consumer shall be considered eligible when the following clauses are complied with:

- The prosumer should be a current customer of the utility that is responsible for the supply of electricity in the area;
- The applicant should not have any outstanding arrears prior to making the application;
- Electricity produced ONLY from renewable energy sources are eligible;
- The applicant must either be the legal owner or have the legal permission from the owner(s) or their legal representative(s) for installing the proposed renewable energy system in the premise;
- Any empty space on the roofs or facades of buildings, car parking areas, garages, factory or industrial buildings or sheds or similar buildings, or at land within the own premise of the consumer, or any other suitable area accepted by Utility where the Utility meter exists, is consider as the rooftop of the consumer and is suitable for the installation of solar PV systems for the net energy metering scheme;
- The prosumer shall consume the electricity at the point of renewable electricity generation, and only export the excess amount to the grid;
- Interconnection standards shall comply with the interconnection rules and standards set by the Utility or other relevant governing authority.

Capacity and Energy Export Limits of Net Metering Policy:

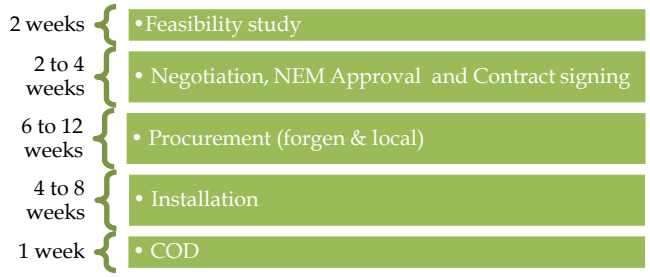
- Any three-phase consumer can be considered eligible for the net metering system.
- A consumer can install (capacity of solar PV system) up to 70% of his sanctioned load.
- Maximum output AC capacity of the installed RE system for NEM can be up to 10 MW.
- For a medium Voltage (MV) consumer, the installed capacity of the RE system can be a maximum of 70% of the rated capacity of the distribution transformers.

The following points have been included in the revised *Net Metering Guidelines (November, 2019)* to facilitate the OPEX model:

- Tariff can be negotiated either as flat rate or a yearly slab purchase rate.
- A "Solar accounting meter" (meter that keep records of energy generated from the solar system) & a "Self-consumption meter" (meter that keep records of energy consumptions by the consumer) will be mandatory for OPEX systems.
- Payment between two parties must be via a proper banking channel or a similar payment system, so that all transactions can be backed with evidence.
- Every meter will be checked every month in the presence of the representatives of both parties, and data should be recoded properly by both parties.
- The consumer will provide 12-month standby LC or equal security to the OPEX system operator.
- After installation of the net energy metering system, a copy of the bilateral agreement between the consumer and the OPEX operator will be added as a part of the trilateral agreement (among the consumer, the OPEX operator and the utility) and should be attached with the agreement.

Lead Time of Procurement / Implementation:

The key components (solar PV panels, inverters, DC cables, etc.) of the solar PV systems are generally imported from different countries of Europe, China, India etc. The local market (Bangladeshi) avails and ensures the quality of other components like protection systems, combiner boxes, AC cables etc. Therefore, the Mega-Watt scale solar PV projects' procurement can be categorized into two parts: the local and the foreign procurement with LC. Foreign procurements have a lead time of typically 30 to 90 days from the opening of LC. On the other hand, local procurements can be completed within 2 or 4 weeks from the work order placement.



Procurement categories:

- Foreign Procurement
  - Solar PV Module
  - Module Mounting Structures (can also be local)
  - Solar Grid-tied Inverter
  - Hybrid/Fuel Save Controller for PV Generator (optional)
  - Monitoring & Communication System
  - DC Cables
- Local Procurement
  - Earthing/Lightning Protection systems
  - AC Cables and Connectors
  - Safety Equipment for O&M
  - Combiner Box / Distribution board
  - Service Walkways
  - Energy Meter
  - Cable Tray

After procurement, installation and commissioning works take usually 1-3 months for a 1 MWp system. This may vary depending on the design and site location of installation of the project etc.

Key Information Required for Implementation:

Before implementing any solar project, the following key information is required for the systems design:

- Total suitable area for installation of solar PV panels.
- Type of available roof in the premise for the solar PV panels installation (RCC or Metal Industrial Shade).
- Tilt (slope) angel & azimuth (orientation) of the roofs.
- Sanctioned load of the factory.
- Factory's hourly (day) and monthly (year) load profile. Source of power: Grid power or captive power or both.
- Load shedding frequency and duration.
- Feasible evacuation points of solar power in the factory.
- Net metering requirements and eligibility.
- Last 12 months electricity consumption and bills

Challenges of OPEX Implementation:

Challenges related to implementation of the solar OPEX model are as follows:

- Since there is always a risk related to long-term performance of the main business of the consumer, timely payments from clients are not always ensured.
- Due to the intermittent generation of solar PV systems parallel operation of PV with captive generator is challenging, and with the intelligent control system sometimes total generated power from the PV system cannot be fed into the internal electric network.
- Grid and load side fluctuation can affect the life of the inverters while using the PV system with captive generation (where grid is absent).
- Consumers tend to prioritize their own compliances, which sometimes cause interruption for the service provider to ensure proper O&M services of the PV assets.
- Absence of dedicated O&M manpower on site due to smaller plant capacities.
- Stocking of spares due to cost constraints in smaller capacity plants.

Photo: Utility building of DPQSL factory at Mater Bari, Valuka, Mymensingh, solar PV inverters are installed on the outside wall of this building

Project cost (considering 1 MWp system):

There are many variable factors that determine the project cost. The cost of module mounting structure varies depending on the installation area (ground mounted or rooftop system). The cost of the mounting structure also varies depending on the type of roof (RCC or Metal Industrial Shade). The efficiency of the solar PV module, the load profile of the consumer, captive generation, project capacity, equipment brand and country of origin/manufacturing etc. are also important factors that play a vital role in the project cost.

The area requirement for installing one Megawatt (peak) of solar PV panels is approximately 8,000 square meters. It may vary according to the pattern of the roof (roof tilt, roof orientation etc.). The unit panel size is in general 2 meters by 1 meter and the capacity of each panel varies according to the efficiency of the solar PV cells. At present, 400Wp to 500 Wp panels are available in the market. An approximate cost estimation of a 1 MWp grid tied rooftop solar PV system with standard equipment is given below [The project cost reference has been taken from recently approved rooftop solar PV projects of similar size in Bangladesh]:

Photo: Factory buildings of DPQSL, solar PV panels are installed on the factory roof of this factory buildings.

Project cost components	Price (BDT)	% of project cost	Unit Cost
Solar PV Module (1 MWp), Product and output warranty: 25 years	24,000,000	46.15%	
Module Mounting Structures	8,200,000	15.77%	
Solar Grid connected Inverter	7,800,000	15.00%	
Hybrid/Fuel Save controller for PV-Generator-Grid	800,000	1.54%	
Monitoring & Communication System	500,000	0.96%	
Energy Meter	100,000	0.19%	
Cleaning system and cable trays	1,200,000	2.31%	
Combiner Box	600,000	1.15%	
Earthing/Lightning protection, with High voltage, 500KV cable and maintenance free chemical earthing	900,000	1.73%	BDT 52/Wp
Cables and Connectors (UV protected)	4,000,000	7.69%	
Spares	400,000	0.77%	
Service walkways	600,000	1.15%	
Safety Equipment for O&M	500,000	0.96%	
Transportation, Installation & Interconnection, Commissioning	1,000,000	1.92%	
Design & Consultancy	800,000	1.54%	
Legal & Other costs	300,000	0.58%	
Environmental Consultancy	300,000	0.58%	
Total Project Cost	**52,000,000**	**100%**	

Annual Savings from adaption of OPEX Model (for 1 MWp solar PV system):

The table has been prepared considering the following assumptions:

- BOOT OPEX Model: Fixed tariff (7.00 taka) for solar PV electricity for 12 years. After that the full operational system will be transferred to the consumer at no cost and from then on the consumer will enjoy almost free electricity for rest of the project life.
- Grid tariff: BDT 8.97 [Industrial tariff of REB at 11 kV]
- Utility tariff escalation: 5% per year
- Project life: 20 years
- Specific energy yield: 1250 kWh/kWp/Year
  [Generation from solar PV system depends mainly on the following five parameters:
  - **Location of the system**: Solar irradiance varies according to the geographic location. For example, in Bangladesh higher solar energy insolation is in the Chittagong and Rajshahi regions and lower solar insolation are in Panchagarh and Sylhet regions.
  - **Orientation of the roof (Azimuth):** South facing roofs receive the highest solar irradiance whereas east, west and north facing roofs receive relatively lower solar irradiance.
  - **Roof angle (Tilt angle):** If the roof is not concrete roof (flat roof), then generally the solar PV panels are installed at an angle equal to the angle of the roof. The amount of solar irradiance depends on the angle of the roof (i.e. the angle of solar PV modules). With a tilt angle of local latitude (For Bangladesh it is between 21° to 26°) facing towards south receives the highest solar irradiance.
  - **Availability of grid:** Almost all the rooftop solar PV systems are grid tied systems. The solar system can generate electricity only when there is solar radiation and the grid is present. During the load shedding hours or the outage hours for grid maintenance, the solar PV system cannot generate electricity.
  - **Dusts on the solar panels:** Solar PV panels are keep in the open roof to get solar insolation. So, dusts accumulates on it. The panels needs to be cleaned on a regular basis. If dusts accumulates on panels, it reduces the solar energy fall onto the solar cells and thus the output energy.
    In optimum conditions: south facing panels with tilt angle equal to local latitudes and no load shedding or grid outage and with premium quality products the annual energy yield can be as high as 1500 kWh/kWp/year.
    Here we have considered annual generation of electricity of the installed PV system 16.67% less than optimum conditions (as an example)]
- Performance degradation of the PV system: First year degradation 2.5%, after that 0.7% linear degradation each year. This value is guaranteed by the panel manufacturers.
- Yearly maintenance cost is considered to be 2% of the initial investment cost. Maintenance cost escalates at a rate of 5% per year. The maintenance cost is an approximate value from the market reference.

Year	Energy produced from Solar PV system (kWh)/year	Grid electricity Tariff, BDT	OPEX Rate (BDT)	Savings on Grid Tariff	Maintenance Cost	Annual savings from Utility bill, BDT
Y 1	1,250,000	8.97	7	1.97	-	2,462,500
Y 2	1,218,750	9.42	7	2.42	-	2,947,547
Y 3	1,210,000	9.89	7	2.89	-	3,496,204
Y 4	1,201,250	10.38	7	3.38	-	4,064,905
Y 5	1,192,500	10.90	7	3.90	-	4,654,436
Y 6	1,183,750	11.45	7	4.45	-	5,265,611
Y 7	1,175,000	12.02	7	5.02	-	5,899,273
Y 8	1,166,250	12.62	7	5.62	-	6,556,297
Y 9	1,157,500	13.25	7	6.25	-	7,237,587
Y 10	1,148,750	13.92	7	6.92	-	7,944,082
Y 11	1,140,000	14.61	7	7.61	-	8,676,751
Y 12	1,131,250	15.34	7	8.34	-	9,436,598
Y 13	1,122,500	16.11	0	16.11	1939525	16,142,638
Y 14	1,113,750	16.91	0	16.91	2036501	16,801,770
Y 15	1,105,000	17.76	0	17.76	2138326	17,486,459
Y 16	1,096,250	18.65	0	18.65	2245242	18,197,612
Y 17	1,087,500	19.58	0	19.58	2357505	18,936,164
Y 18	1,078,750	20.56	0	20.56	2475380	19,703,078
Y 19	1,070,000	21.59	0	21.59	2599149	20,499,342
Y 20	1,061,250	22.67	0	22.67	2729106	21,325,975

Accumulated (cumulative) savings in project life (20 years): BDT 217,734,829

Photo: Installed Solar String Inverters on the utility building wall of DPQSL factory at Mater Bari, Valuka, Mymensingh.

General PPA Terms:

Key responsibilities of the Industry:

- The consumer shall handover the site in good, safe and buildable condition and give the OPEX operator peaceful and quiet possession throughout the PPA tenure.
- The consumer shall at all times ensure physical security of the plant.
- The consumer shall obtain necessary approvals/permits for installation, commissioning, and operation of the plant.
- The consumer shall ensure timely payment of the electricity invoices to the OPEX operator.
- The consumer shall provide the OPEX operator a payment security mechanism (revolving LC of 12 months equivalent of energy tariff) which shall be valid for the entire term of the PPA.
- The consumer shall provide corporate guarantee up to the extent of buyback price (if triggered due to default) on the trigger date.

Photo: Production line of Debonair Padding & Quilting Solution Ltd. (DPQSL).

Key responsibilities of the OPEX operator:

- The OPEX operator shall use only globally reputed equipment brands with standard international performance warranties.
- The OPEX operator shall be responsible that the plant is commissioned within the agreed timeline in accordance with prudent utility practices.
- The OPEX operator shall be responsible for the operation and maintenance of the plant, ensuring safety of the employees and assets of the consumer.
- The OPEX operator will ensure no damage to the roof structure during the contract term.
- The OPEX operator will provide the performance guarantee of the installed PV system. (i.e. need to ensure the delivery of a certain energy per year).

Other Conditions:

- Both parties will enter into a Power Purchase Agreement (PPA) as per the satisfaction of the financier/lender who will extend financing to the OPEX operator for implementing the solar power plant
- The consumer agrees to provide step-in rights to the lenders entitling the lenders to step into the role of the OPEX operator and assume all its roles, responsibilities, and benefits under the PPA
- In case of any Force Majeure event, the affected party will immediately notify the other party and each party shall at all times use all reasonable endeavors to minimize any damage as a result of a Force Majeure event.

Possible Sources for Financing

SREUP credit line could be a good source of financing for such an investment.

Main Feature of SREUP Credit Line	
Loan Type	Normally Term Loan
Discount	Provision and possibility of 20% discount from loaned amount
Loan Tenure	3-5 years in general and in special case up to 7 years
Loan Limit	Normally up to 1 Million Euro and can be increased up to 3 Million Euro in special cases
Interest Rate	7% p.a. (maximum)
Grace period. Debt: Equity Ratio. Repayment	All issues are subject to agreement between borrower and lender

Infrastructure Development Company Ltd. (IDCOL) is providing concessional financing for solar rooftop projects. Key financing parameters of IDCOL financing are as follows:

Loan Type	Term Loan
Loan Tenor	10 years
Loan Amount	Maximum 80% of Project Cost
Debt : Equity ratio	Maximum 80 : 20
Grace Period	1 Year (principle only)
Repayment	Monthly
Interest Rate	6% p.a. (fixed)

Case Study Spotlight (CAPEX model): Debonair Padding & Quilting Solution Ltd. (DPQSL)

Debonair Padding & Quilting Solution Ltd. (DPQSL) is a sister concern of Debonair Group. Debonair Group is a privately owned, diversified but mostly inter-linked garment manufacturing and agro business platform. It consists of six operating entities worth $60.0 million, of which four businesses are export-oriented and profit-making organizations and the other two operate as non- profit-making organizations. The company has started its manufacturing journey in 2010,

DPQSL started its commercial production on 28 April 2017. The factory is located in Valuka, Mymensingh Industrial Area, where they have installed advanced Auto Computerized Padding & Quilting machines. The factory floor is 150,000 sft, and currently, 100 expert employees are engaged in padding and quilting production with foreign consultants.

This project is the first OPEX-operated rooftop solar PV system in Bangladesh.

Description of the project:
OPEX Consumer: Debonair Padding and Quilting Solution Ltd. (DPQSL)
Location: Paragon square, Mater Bari, Valuka, Mymensingh.
GPS Co-ordinates of project site: 24. 3028 °N, 90. 3534 °E
Sanctioned load from Utility: 2000 kW.
Peak load of DPQSL: 1000 kW
OPEX operator: Megaroof Ltd.
Capacity: 324 kWp
Model: OPEX
Project cost: BDT 25,500,266
Commercial Operation Date (COD): 1 March 2019

Photo: AVR (Automatic Voltage Regulator) voltage regulator and stabilizer in the factory in case of voltage fluctuations in the grid, which also supports the smooth operation of the grid tied inverters.

Feature of the PPA

1. Tariff of consumed energy from OPEX operator is 5% lower than BREB tariff.
2. Roof lease agreement at BDT 1.00/sft/yr. [the factory owner is the lessor and the OPEX operator is the lessee]
3. Asset handover (the transfer of the operational solar PV system) to the consumer will take place after 12 years of operation, free of cost.
4. Pre-payment option to buy the asset any time after 5 years of operation at a fixed price, depending on the year of purchase.
5. Payment security in the form of BG (bank guarantee), equivalent to 2 years payment.

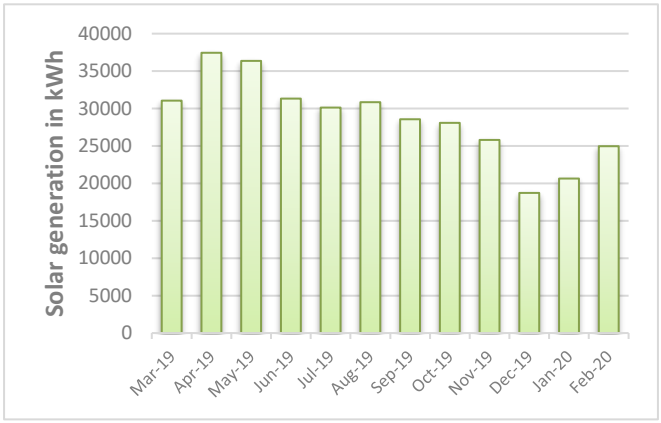
Project design description

Solar PV capacity: 324 kWp [1200 panels of 270 Wp each]
Inverter capacity: 300 kW [5 solar string inverters of 60 kW each]

According to the design, the capacity of the solar PV power plant is 324 kWp and the generated power feeds directly into the factory's power distribution system. Roof shed of the DPQSL are south and north facing with inclination of about 10 degrees. Both sides of the roof (south and north facing) have been utilized for solar PV panels installation. Solar PV inverters are installed outside of the north east corner of the utility building. Solar modules are installed with aluminum flash mounted structures to the roof. The generated power from the solar PV system is used by the DPQSL for captive use. DPQSL has become the NET energy metering consumer of the utility (BREB), so if there is any excess solar energy (not utilized by DPQSL), it is fed into the grid through a bidirectional meter. The meter will keep a record of the exported energy (to the grid), and that will be adjusted from the electric energy that is consumed by the consumer from the grid.

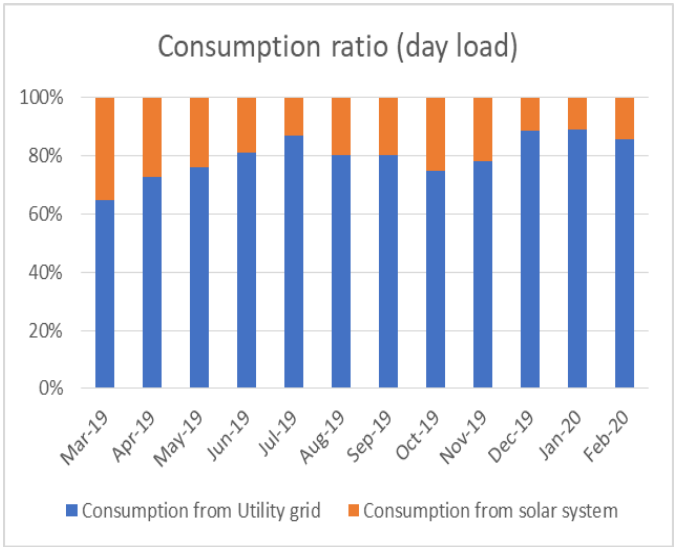
Generation data analysis

The solar power plant is operational since March 2019. The energy generated by the PV array has been recorded monthly form the electricity meter. Graph-1 shows the monthly generated solar energy from March 2019 to February 2020.



Over this 12-month period the system generated a total of 343,889 kWh (Units) of electricity. Of this, the highest generation of 37,440 kWh is in the month of April 2019 & the lowest is in the month of December (18,720 kWh). During winter months, the generation is at its lowest, as half of the solar PV modules have been installed on the north facing roof of the factory sheds with a tilt angle of 10 degrees. So, the solar incidence angle during noon of the winter months is more than 55 degrees. Thus, the half of the installed solar PV panels (installed in north facing roof) get less irradiance during the winter and thus the energy yield is at its minimum during winter months. And there are outage of power for load shedding and for maintenance, thus the annual energy yield is lesser than the ideal case.

The next Graph (graph 2) shows the electricity consumption ratio between the utility energy & the energy from solar system of the factory.



Solar energy is available during daytime, so consumption is considered for only day time, which is the off-peak period for the utility. PV power supported around 20% of factory's total day load. The PV installation has reduced net electricity consumption by 35% in the month of March 2019 (which is one of the highest solar energy yield months in Bangladesh).

The load of the factory is increasing day by day, so extension of this project is required in future. There are six newly constructed roof shades in the factory which can be used to install more solar PV systems. This additional solar power will help the factory to reduce its energy cost.

Another view of production line of Debonair

String inverters combiner box (i.e. solar distribution box)

Photo: 2 X 750 kVA diesel generators, runs during the load shedding hours, Electricity from solar PV systems reduces the load of these generators during load shedding hours

Installed Solar panels on the south facing roof.

Installed Solar panels on the north facing roof