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Rooftop Solar:A Sustainable Energy Option for Bangladesh

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Abstract:*With the pace of rapid developing economy, the energy demand is increasing day by day which has become a major concern in energy sustainability of Bangladesh. Presently, most of the energy is spawned by burning limited fossil fuels whose reserve will be extinguished very soon. To overcome the present energy crisis, it is high time to find a suitable alternative source for sustainable energy generation. In this regard, solar energy is one of the potential source because of geographical location. Bangladesh government has already taken different kinds of projects to produce desired amount of power by using this solar energy potential. However, numerous common misperceptions appear in the country regarding solar energy potential. One of the foremost problem is acquiring adequate land for solar park, Bangladesh being an agro-based country obtaining land is very difficult for setting up large solar power plants. On the other hand, residential, industrial, commercial and government buildings can provide enormous rooftop spacewhich can be used to implement for solar power production. Therefore, rooftop solar is the best alternative resolution for Bangladesh to meet its desired target and alleviate the present energy crisis. In this paper we have discussed about present condition and prospects of rooftop solar in the perspective of Bangladesh.*

Keywords*:Rooftop solar, solar potential, net-metering, industrial rooftop, battery, renewable energy, solar power, off-grid solar, on-grid solar.*

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I. Introduction

Society and human development are highly interconnected with proper energy supply. Access to sufficient energy empowers human development, reduces the daily burdens of the poor, creates new economic opportunities, and allows the delivery of critical services ranging from health care to education [1]. This energy empowerment is very crucial for developing countrylike Bangladesh where insufficient power supply is one of the major barriers for economic development [2]. At present 90 % people of Bangladesh have access of electricity [3]. In the fiscal year (2018-2019) per capita energy generation in Bangladesh was around 464 kwh [4], whereas neighboring country India has per capita energy generation around 1,181 kwh in (2018-2019) which is more than twice compare to the Bangladesh [5]. The demand for energy is increasing rapidly in different sectors of Bangladesh. As the country is flourishing with more industries, mitigating the demand for more power is becoming a challenge.There remains always a huge difference between energy generation and demand in Bangladesh [6]. In order to covenant with the present energy crisis, a workable scheme must assuredly be improved [7]. At present 97% of total power is generated by using fossil fuels in Bangladesh which isdetrimental for the environment [8]. As a tropical country Bangladesh is enriched with solar energy which is a dependable, inexpensive and effective energy for the country [9]. Due to decreasing manufacturing cost, improved design and efficiency, large scale production, durability makes the solar power as a proper competitor to the conventional energy [10]. Bangladesh government has already planned some solar projects for producing electric power by utilizing this solar energy potential [11]. Butmaximum of the planned solar projects in the past few years have been frequently hindered [12]. This is because; acquiring land for solar park is one of the main barriers. As solar PV power plant require minimum one hectare/MWp, it requires vast land for large scale solar PV power plant. Maximum of the lands are agricultural lands and the ownership of the lands are several hundred persons [13]. Due to dearth of land obtainability, rooftop solar offers a feasible solution to scale up solar power generation in Bangladesh because Bangladesh holds massive rooftop solar potential [14]. Most of the government, industrial, commercial and residential buildings are fully or partially vacant in this country [15]. If this solar rooftop potential placed to use the power crisis of Bangladesh will significantly be reduced and per capita energy generation will massively increase [16].

This paper reviews the present scenario of rooftop solar and the prospects of this technology in context of Bangladesh.

II. Potential for Rooftop-based Solar in Bangladesh

Bangladesh is gifted with reasonably good solar energy potential. The geographic location of Bangladesh is in between 20.300 and 26.380 north latitude. As Straddling the Tropic of Cancer, Bangladesh is blessed to get average 5 kWh/m^2 radiated solar energy throughout the annum. But due to heavy rainfall, winter fog and other calamities approximately 65 days per annum are subtracted from the above calculation. Total land area of Bangladesh is 1.49E+11 m^2 and it is very suitable to get maximum solar energy from the sun. By observing we can get maximum solar intensity between the months March to April and minimum solar intensity throughout December to January. A study estimated that in Bangladesh, the daily sunlight hours varies between 7 to 10 hours. It may be reduced by 54% approximately due to cloud, rainfall and fog. So, during the suitable period this huge amount of solar energy has a large potential which can be used in various sectors in Bangladesh [17], like Germany, which is one of the big proponents of rooftop solar installation. As of September 2018, total installed capacity of solar systems in Germany is 42,000 MW, of which rooftop solar installation accounts of 71.4 % [18]. The average solar irradiation in major cities of Bangladesh is higher than any other cities in Germany.The following fig.1 shows a comparison of rooftop areas in two urban hubs of Bangladesh and Germany. It is visually evident that urban cities in Bangladesh have more rooftop based solar potential compared to German cities. Unluckily, no detail study has been done exploring the total rooftop potential in Bangladesh so far [19].

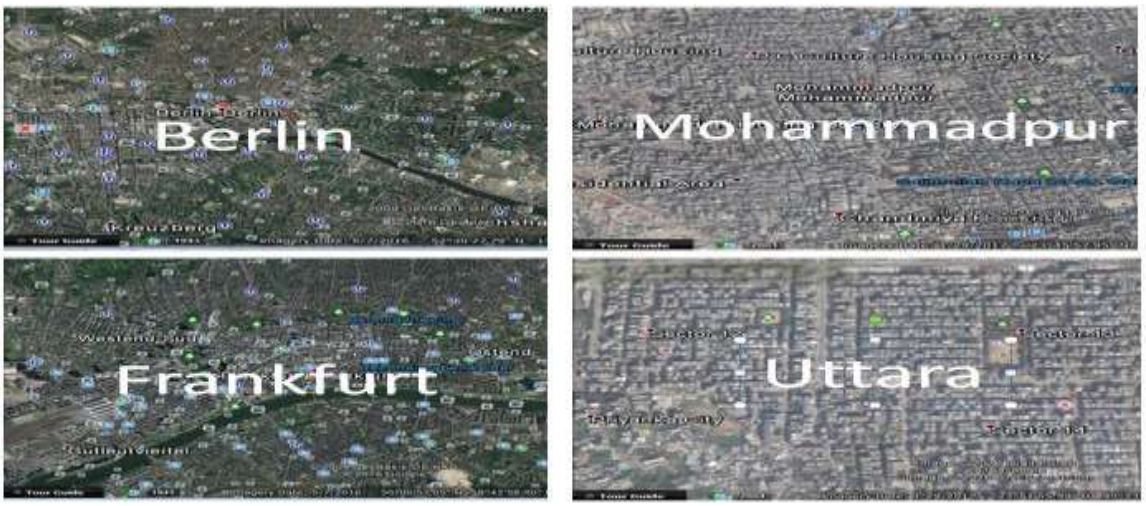

Fig.1 Comparative visuals of urban based rooftop solar potential for Germany and Bangladesh [19].

2.1 Advantages of Rooftop Solar Systems in Bangladesh

- Opposing climate change – Fossil fuels are highly responsible for global warming. Solar energy does not make any harmful effect on the environment. Thus, it reduces a substantial amount of greenhouse emission.
- Resilient& reliable – Solar system is a lengthy investment. It continues up to 25 years.
- Reduces the electricity cost – No matter which of solar panels consumers install, it brings a histrionicdecrease in electricity charge.
- Cost-effective – Solar system needs less conservation. Once a consumer installs it, he will notice how much money he spent on electricity all these years.
- Profusion – The sun will shine every day. Take full benefit of the free energy we are gifted with.
- Generatesoccupationchances – When consumers install the solar system automatically make a job with the native community.
- A safe investment – It is absolutely a safe investment that can benefit consumers make some extrarevenue. On-grid system transfer power to elsewhere leaving consumers with some extra cash [20].
- Utilization of vacantrooftop space of industrial, residential commercial and government buildings, e.g. 100 sq.ft./KWp.
- Inexpensive electricity than that of grid for industrial consumers.
- Practicalpayback period e.g. 6-7 years [21].

III. Net-metering System

Bangladesh government was published a net metering guideline in July, 2018 to inspire the industrial, residential, government and commercial buildings power consumer to adapt rooftop based solar energy technologies. Net-metering system is a system where the owner get their regular electricity bills adjusted by feeding solar electrical energy to the national grid. When solar power is not used by the residential,

government,industrial and commercial, buildings power consumers during holidays and for other causes, the solar electricity can still be sold to the national grid. The bill is adjusted at the close of each month based on the electricity added to the national grid produced from solar [22]. In the scheme, the consumers, who use electricity from the grid be able to set up a rooftop solar system, covering up to 70 percent capacity of the authorized load. Their bills can be attuned by a special meter which can regulate how much they are receiving from the grid and deliver to the grid.This system will save a hugequantity of electricity on the subscriber 'canregulates electricity bill [23]. Rooftop solar installment price is greatpayback period is around 7 years however its lifetime is 25 years. So, one can be benefited in the long run [24].For net-metering system many consumers are eager to adapt this technology. At present 117 rooftop solar systems under except net-metering system with the capacity of 41.187 MW in Bangladesh [25].

3.1 Net-metering: Advantages

- Net-metering strategy is making the users extra interested in rooftop solar than earlier.
- Existing on-grid systems are effortlessly convertible to net-metering with extra only the net-meter and installing solar panel.
- Energy produce for net-metering system are improved due to possibility of transfer of excess energy while own consumption is low.
- Mass consciousness of net-metering strategy and paybacks among the stakeholders will make more demand and prospect for rooftop solar.
- Other than industries establishment with major day time consumption like schools, colleges, universities and offices have abundant opportunity to benefit the advantage of net-metering.

3.1.1 Net-metering: Disadvantages

- The quantity of exported energy might be point out in utility bill for well clarity and motivation for the consumer.
- In some circumstances, it is taking some time to adjust the bill for software upgradation of the utility agency.
- A proper PPA (power purchase agreement) with private sector with engagements of utility agencies will significantly enhance the expansion of rooftop solar under net-metering.
- Initial cost of installment is high.
- Other aids like accelerated depreciation to be considered.
- VAT and other tax rebate for the solar energy produced will also enhance the rapid growth of rooftop solar with net-metering [26].

4.1 Rooftop Solar for Residential Buildings

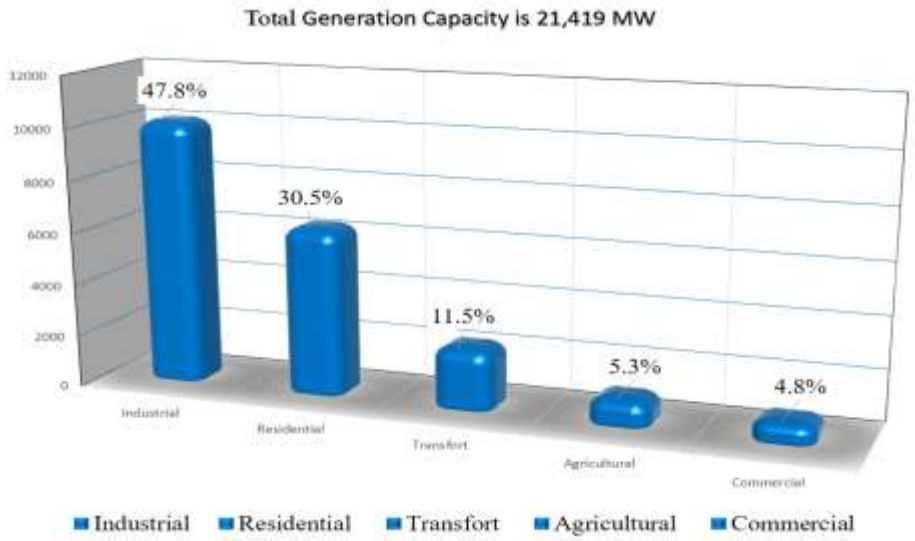

Fig. 2 Primary energy consumption in different sectors [27].

From fig. 2 we can observe that 30.5% of total energy is being consumed in residential sector in Bangladesh, which is the second largest power consumer in the country [27]. There is a vast market for rooftop solar within the residential sector. For collectivecauses, there needs to be some leeway within the residential segment. Obviously not all homeowners will have the capability to finance in solar power. An issue which will

need to be resolved for the residential sector is that each building will only get one net-meter. Though everyone has distinct electric meters, the building will have to enjoy any savings as a whole and not independently. Whether this will become a problem remains to be seen. For the residential sector, the net-metering rules state that the maximum installation capacity for a residential building should not surpass 100kW. This also is an unnecessary barrier for which can be reviewed. However, measures to address alternate or alongside use of imperfect rooftop space must be developed. The usage of securely mounted, elevated solar panels for shading; should be explored [28]. Solar Home System (SHS) which is one type of rooftop based solar system has a success story in rural areas in Bangladesh, the project has been acclaimed as one of the biggest and the fastest increasingoff-grid renewable energy program in the world [29]. SHS has successful in rural areas of Bangladesh, it can be successfully done in urban areas too [30]. To meet the ever growing electricity demand in the urban area, roof-top solar PV (photovoltaic) offers a reasonable and alternative resolution along with conventional power supply from the electricity grid. As scheduled load shedding is a daily phenomenon in this nation, the Instant Power Supply (IPS) units have become very widespread. IPS stores electrical energy from grid power and uses the stored energy on load shedding. Rooftop solar power can easily replace this burden [31].

4.1.1Different types of PV or solar power installation

There are mainly 3 kinds of PV. Each of them comes with unique features and limitations too. They are discussed below:

4.1.1.1 Grid-tied system solar

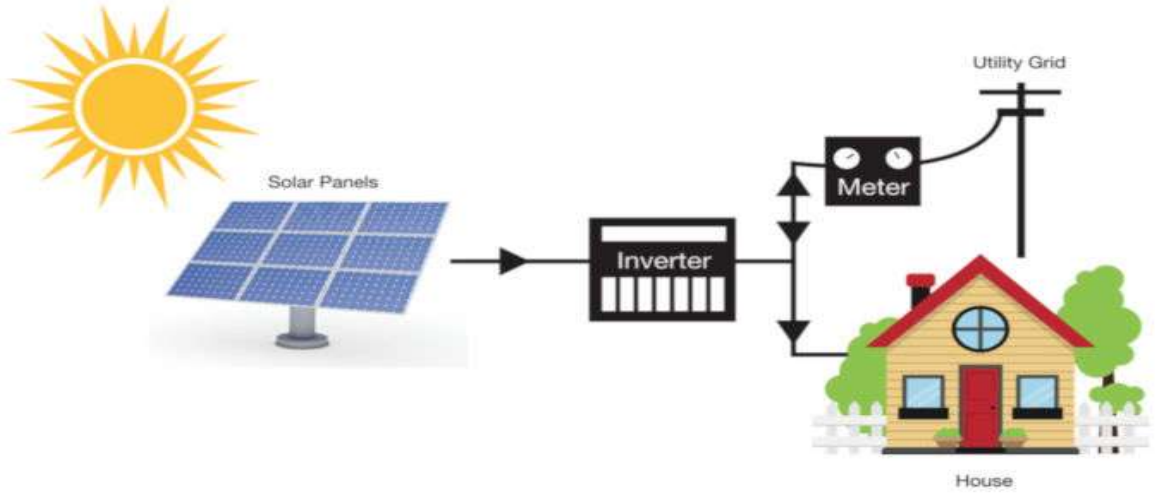

Fig. 3 On-grid solar system without battery backup with net metering system [32]

On-grid or grid-tied solar system is linked to the electrical grid, thus, it can draw energy from both solar panels and the electrical grid. This system is the most common type. It uses a common solar inverter. The excess energy that consumersproduce is transferred to the grid for use somewhere else [33]. Grid-connected solar PV power generation has marvelous potential for accelerating power generation capacity in Bangladesh [34]. This is a regular type for those who want to cut down some electricity bills. Net-metering will cost additional installation charges, but consumers can save much more over the lifetime [35]. In Bangladesh on-grid installed capacity is more than 42 MW, but all of them are not connected through net-metering system [36].

Table 1. Some examples of on-grid solar power running projects in Bangladesh [37].

Project name	Technology type	Capacity (MW)	Location	Completion date	Present Status
Rooftop solar at Kodda 150 MW dual fuel power plant	Rooftop solar (on-grid)	0.02	Gazipur	28/06/2017	Completed & running
Army solar project	Rooftop solar (on-grid)	0.25	Dhaka	31/12/2015	Completed & running
BCSIR solar power plant-01	Rooftop solar (on-grid)	0.06	Dhaka	01/07/2014	Completed & running
BCSIR solar power plant-02	Rooftop solar (on-grid)	0.06	Joypurhat	01/07/2012	Completed & running

4.1.1.2 Advantages of the on-grid system

- The setting up is much more cost-effective and needs very small maintenance.
- The surplus electricity produced can be sold back to the grid. It can be anextra income for houses.
- As it can feed and receive energy from grid, one of the options always remains backup in the case of power failure.
- Low average cost per unit (kWh) of electricity.
- Solar energy is free, so there is no require of extra cost for fuel.
- Cut on diesel consumption in generator.
- Synchronized with the present power system.
- Lengthy system life time: each of them can serve up to 25 years.
- No electricity price hike during the plant lifetime.
- No extra space is necessary; the system is set in the vacant rooftop.
- Transfer the extra electricity to national grid under net-metering policy [38].

4.1.1.3 Off-grid solar system

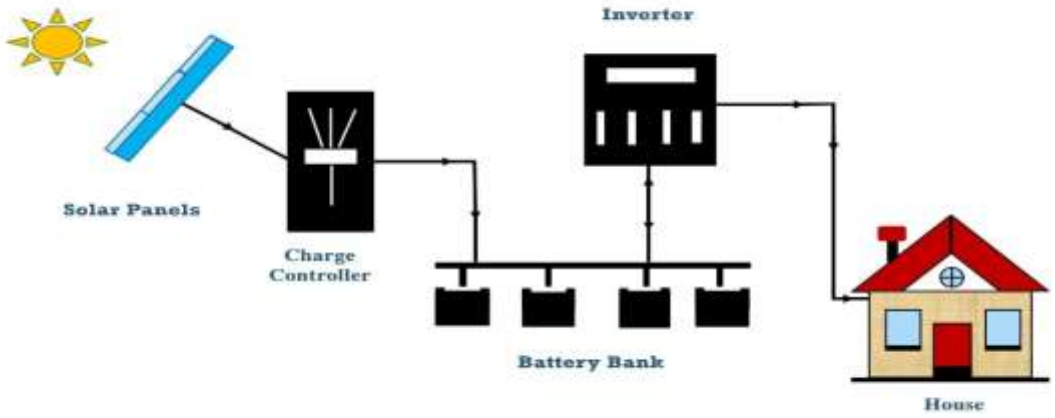

Fig. 4 Off-grid solar system [39].

These systems work independently hence requires a battery for conserving energy. The panels absorb energy during daylight and utilized the generated power at night. The batteries and inverters are much costlier. They require special tools to produce power all over the year. This system is relatively expensive. They provide energy in critical hours and mostly used in remote areas where the electricity grid is not available [40]. Bangladesh has a successful story in developing off-grid rooftop solar power known as solar home system (SHS) which has given electricity to a huge number of people living in rather distant off-grid areas [41]. Bangladesh has one of the world's leading domestic solar power systems, casing 14% of its total population [42]. Almost 5.5 million solar home systems installed in Bangladesh, and it can produce around 233 MW electricity.As SHS replacing kerosene, the government is saving US$225 million yearly on kerosene imports. With the emergence of solar home systems, kerosene imports have reduced which brings down the country's economic burden [43].

Table 2. Two examples of running off-grid solar projects in Bangladesh [44].

Project name	Technology type	Capacity (MW)	Location	Completion date	Present Status
Ashuganj 32 KWp Roof Top Solar System	Rooftop solar (off-grid)	0.03	Brahmanbaria	19/10/2016	Completed & running
Ashuganj 40 KWp Roof Top Solar System	Rooftop solar (off-grid)	0.04	Brahmanbaria	12/03/2017	Completed & running

4.1.1.4 Advantages of the off-grid system

- Power failure do not affect these systems since they work individually.
- Easy alternative for remote areas where no grid electricity.
- Easy maintenance [45].

4.1.1.5 Grid-tied with a battery backup system or Hybrid Solar System

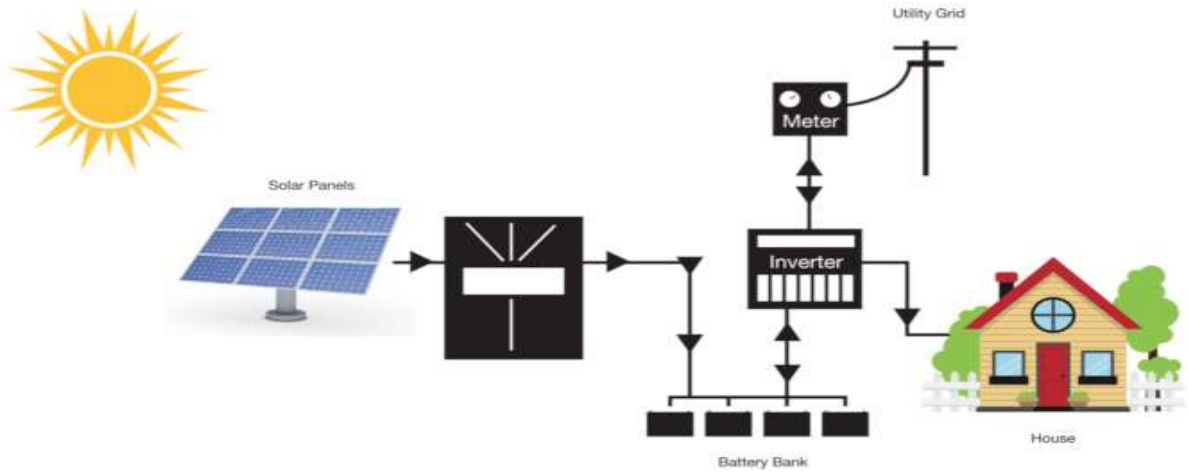

Fig. 5 A hybrid solar system [46].

This scheme is more like on-grid solar power with special hybrid inverters. Consumers can use power from the grid when required. The only added feature is that during emergency power cuts the backup battery delivers power when required [47]. The battery adding makes this system aclever one. The abundant light often leads to too much energy, which the battery stores up during power cut. A grid-tied system with battery backup is merelyreliant on the sun; hence, it might not generate much energy during winter time. The installation of the battery is costlier because of the complexity of the scheme. It is not popular yet in Bangladesh, because it requires very high cost in initial installment [48].

4.1.1.6 Advantages of Hybrid solar system

- Agree to use of stored solar energy during peak evening times.
- There is no condition for backup generator.
- Decreases power consumption from the grid [49].
- Hybrid solar system can be the best option for solar powered battery charging station in Bangladesh [50].

4.2 Rooftop Solar for Industrial and Commercial Buildings

From fig. 2 we can get a clear view that around 47.8 % of total energy in Bangladesh are being consumed in the industrial sector. The industrial sector is the largest consumer of power in Bangladesh [51]. Up to June 2019, total 286,469 industries introduced rooftop solar on their vacant roof in Bangladesh. Besides economic benefits, rooftop solar enriches green credentials of industries while indicating environmental accountability to stakeholders. Rooftop solar expose enormouschances for industrial consumers to make use of their idle roof spaces for ample solar power generation at comfort with least maintenance, thereby decreasing use of grid electricity. Around 100 square feet or 10 square meters of roof space is required for installation of one kilowatt peak (kWp) rooftop solar system [52]. Industrial solar power systems are gradually gaining popularity in Bangladesh. The major industry firms are now considering solar power. The motivation behind this is net-metering policy. Industrial solar power systems are highly cost-effective and ideal for RMG (ready-made garments), textile, cement, paper, steel, chemical, dairy and ceramic industries to reduce their electricity costs. Over a 30-year project life of these solar solutions, the charge of electricity production is less 5 tk. per unit, building it economical than gas generated power [53]. The RMG and textile sector can be one of the foremost producers and users of rooftop solar power. According to the IDCOL(Infrastructure Development Company Ltd.) 1,500 members of the Bangladesh Textile Mills Association have 42 million square feet of rooftop space, which could be used to install solar PV system which can provide 400MW. Textile sector is the largest GHG (greenhouse gas)emitter among industries, accounting almost 38 per cent of GHG emissions. It is imperative to diversify their energy sources including exploitation of available renewable energy potential. Rooftop solar PV can be a right option to replace some percentage of the usage of fossil fuels. According to a study conducted by IFC (International Finance Corporation), with rooftop solar, factories could decrease grid power consumption by 5 to 20 per cent. Improvement of rooftop solar sector could create jobs as native capacity of private financiers and other value chain performers would be advanced [54]. The textile sector is considered as one of the maximum energy consumers in the industrial sector of Bangladesh. The sector represents 81% of aggregate revenue of the country. Presently, the textile industry in Bangladesh has more than 5600 factories, which is likely to increase further [55]. Some of the world's prominent textile brands are produced in Bangladesh and have become environmentally aware. They are gradually having policies to import

products from sustainable sources. By seeing overall situation rooftop solar is the paramountoption for textile industries. The RMG sector in Bangladesh, the country's foremostindustrial and export sector, has a target vision to reach $50bn in exports by 2021. While the textile and in particular the garment industries are very essentialusers of electricity, PV electricity Production and Consumption might be appropriate for other important industries such as pharmaceutical, chemical, cement, food and tannery industries. All those industries consume electricity and can only be set up in large facilities. However, the energy intensity of the many procedures is very high and typically machines need to run 24/7 throughout the year. Rooftop PV might only cover a very small share of the electricity required, thus not generating a lot electricity to inject into the electricity. In addition, especially cement and chemical industries also have a very demand in high temperature heat and can be found in direct proximity of conventional power plants in many nations [56].

As solar power has turn intoinexpensive compared to grid electricity for industrial consumers, using solar power reduces their electricity bills together with net-metering scheme has created an enabling environment for industrial consumers to monetize unutilized roof space through installation of rooftop solar. Taking benefit of this favorableatmosphere, few industrial users came forward to install rooftop solar system [57].As the outline of net-metering systems, the power generation from rooftop solar of industrial units has already touched around 18 MW [58]. As for example, some industries using their unused roof space for producing solar power are given below:

Table 3. Some examples of industrial&commercial rooftop solar projects in Bangladesh[26, 52].

Project name	Technology type	Location	Capacity	Present status
Rooftop solar for Paragon Poultry Ltd.	Industrial rooftop solar	Gazipur	723.06 kW	Completed & running
Rooftop solar FESIL	Industrial rooftop solar	Habiganj	1.1 MW	Completed & running
Rooftop for Tosrifa industry ltd.	Industrial rooftop solar	Dhaka	50 kWp	Completed & running
Rooftop for M&U packaging industry	Industrial rooftop solar	Dhaka	200 kWp	Completed & running
Rooftop for Basundhara industrial complex	Industrial rooftop solar	Dhaka	2.46 MW	Under implementation
Rooftop for Robintex group company	Industrial rooftop solar	Narayanganj	3.1 MW	Under implementation
Rooftop for Dhaka stock exchange	Commercial rooftop solar	Dhaka	47 kWp	Completed & running

From fig. 2 we noticed that 4.8% of total energy is being consumed in commercial sector in Bangladesh. The ever growingfee of electricity is beating the operating cost of business. Alternatively, the present source of electricity, fossil fuel is growing the cost on environment by generating GHGs, as a minimum 1 kg per 5 kWh electricity. Seeing the business cost and environmental charge, world is moving towards solar power as it can generate grid quality electricity in low per unit price for around 20 years without generating GHGs. World famous Affluence 500 companies including Google, Apple, General Motors, Microsoft are consuming solar power to run their essential facilities. Generating electricity from solar power using the unused rooftop is also getting popular in Bangladesh as Bangladesh is blessed with abundant sunlight and long daylight hour due to its geographical location [59].Commercial buildings should be undertakingtogether with the industrial sector as they are bigusers of electricity such as GP House, Sonatori Tower, RFL Center and Bashundra Group's Corporate Head Office etc. Maximum large commercial buildings use central cooling systems or large AC systems which consume a lot of power right when solar generation is highest. They also use other equipment, large servers, photocopiers and printers. These buildings typically consume power for more than 12 hours a day and many do these 6 days a week as well. Having these buildings net-metered and using rooftop solar would be an outstanding step on the way todecreasing pressure on the national grid and energy efficiency. For commercial buildings the maximum allowable installation capacity has been set at 500kW, which can be reviewed [60]. There is a lots of opportunity to install rooftop solar in commercial buildings. The government has recently initiated a program to generate 500MW of solar based electricity for the national grid. In this program rooftop for commercial buildings is included. According to SREDA (Sustainable and Renewable Energy Development Authority) commercial building have potentiality to provide surplus 10MW of electricity to grid by using their unused rooftop [61].

4.3 Rooftop Solar for Governmentand Semi-Govt. Buildings

Government buildings including government workplaces and universities still do not use as much electricity compared to the private commercial buildings. But their tariff is higher in compare to residential buildings. Newer government buildings consume more power as they have elevators and air conditioners. Generally, government buildings are prioritized energy consumers [62]. According to SREDA rooftop solar

system has huge potential in Bangladesh by using this potential 1000 MW of electricity can simply be generated of which 400 MW will be on government/semi-government owned buildings [63]. BR (Bangladesh railway) is a big consumer of electricity and it can install solar panels on its own and can provide surplus electricity to the grid [64]. Bangladesh railway stations and junction has lots of unused rooftop. Bangladesh Railway can provide its space of around above 10 million square feet of rooftops. Once such rooftop solar power projects are applied, they will generate 91 GWh of electricity per annum, saving Tk.54 crores per year. In 20 years, savings might touch about Tk.1,078 crores. Initially, 6 major railway stations and offices, 17 junctions and five workshops of the railway were targeted for the rooftop solar project. Primarily, about 100 MW of solar power is planned to be generated with facility of net-metering system by using the rooftops of the railway setting upthrough the country with investment from the private sector. Nearby country India has already implemented a huge number of rooftop solar projects using the rooftops of its railway stations and other establishments which have been running very successfully [65].For government buildings, load is not a limiting factor as the power produced from the rooftop PV from such buildings is bought openly by the utility [66].Some of the early installations in Bangladesh are on government buildings is given below:

Fig. 6 Rooftop solar at Bangladesh bank**(**left**)**, rooftop solar at WapdaBhaban(right) [67]

Table 4. Some running rooftop solar projects of govt. building's in Bangladesh [26, 37]

Project name	Technology type	Location	Capacity	Present status
Rooftop solar for Bangladesh bank	Rooftop solar	Dhaka	20 kWp	Completed & running
Rooftop solar for WapdaBhaban	Rooftop solar	Dhaka	33 kWp	Completed & running
Rooftop BUET	Rooftop solar	Dhaka	78 kWp	Completed & running
Rooftop US embassy	Rooftop solar	Dhaka	20 kWp	Completed & running
Rooftop Solar for Honorable Prime Minister's office	Rooftop solar	Dhaka	20 kWp	Completed & running
Rooftop for REB Head Office	Rooftop solar	Dhaka	49 kWp	Completed & running
Rooftop for Bangladesh Bureau of Statistics building	Rooftop solar	Dhaka	200 Kw	Completed & running
Rooftop solar for government food storage silo	Rooftop solar	Dhaka	360 Kw	Completed & running

4.4 Rooftop Solar Powered Battery Charging Station

Batteries are used in different way, some are used in vehicle, some are in IPS and some are used in machineries. Maximum amount of batteries in Bangladesh is used to run the electrical vehicles such as easy bikes and two seated rickshaws [68].

Fig. 7 Two types of electric vehicles in Bangladesh easy bike (left), two seated rickshaws (right) [69]

Nearly 900,000 easy bikes in Bangladesh which operate on battery power. Presently batteries are charged through main supply electricity. At present, about 900MW energy is used daily from the supply grid in order to meet easy bikes charging demand. This has caused in more energy crisis and load shedding in Bangladesh. Solar powered battery charging station is the hopeful alternative and environmentally sustainable resolution to meet up the on-going energy crises and to boost the present battery operated vehicles [70]. Maximum easy bikes charge their batteries by connecting illegally to the power grid, depriving the government of a huge amount of revenue [71].

4.4.1 System design battery charging station

Fig. 8 A general fuel filling station [72]

By installing solar powered battery recharging stations it can reduce the electric vehicles battery charging problem in Bangladesh. This process can run alongside the normal CNG filling station or petrol pump, as per the solar panels would be attached on top of its rooftop, so there is no need of extra land. This system can work in almost every part of Bangladesh as the whole country face almost same solar insolation enough to produce required electrical energy. The PV modules can be set up on the rooftop of fuel filling stations. Vacant roof can be optimal place to plant the solar panel. As the sun radiates its maximum energy at an angle which can be varied from place to place, in Bangladesh it is preferred to tie the solar panel at 23^0 to get highest efficiency. Capacity of the PV module should be selected taking in consideration the rooftop size for accommodating the panels and the desired output. Almost 10KW power must be supplied during charging 10 electric vehicle at a time. Since charging the battery of each vehicle will take 850-1000W primarily. DC combiner box will also be placed on the roof of the fuel filling stations. The control sections control the whole system which is attached with the output devices or a Personnel Computer. Also a meter is connectedwhich continuously measures the electrical supply and the data is sent to displaying unit. This can be a Personnel Computer or other type of display unit. If it a PC, there is a benefit to collect the data for advance analyzing. Since the battery is DC powered there is no need to connect with any inverter to charge the battery [73].

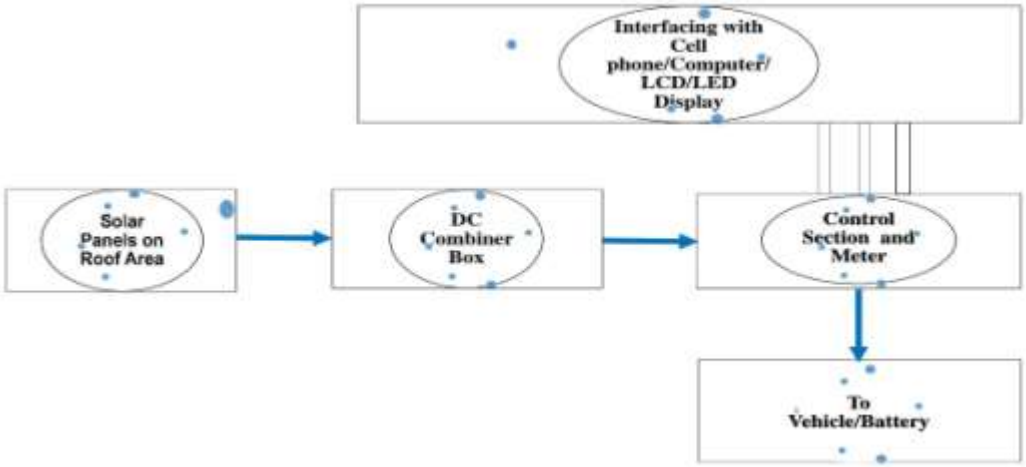

Fig. 9 Total system's block diagram [73].

4.4.2 Opportunities and Benefits

- There are almost 900,000 easy bikes roaming everyday all over Bangladesh. If they can be charged through charging station which utilizes solar power, then power crisis can be reduced.
- A research shows that if negative pulse charger is applied with conventional solar charger, then charging efficiency can be 22% increased.
- Negative pulse charger can control the battery temperature about 50% less if we compare it to the normal conventional battery charger. As the temperature is controlled so the water evaporation is also low. It can extend the battery lifetime. Another way to improve the battery lifetime is to implement Auto Pulse Battery Desulfator during charging the battery [74].
- To recharge these huge amount of easy bikes, more than 900 MW power is consumed. As the owner are poor people, most of the time they charge their bikes through illegal electricity connection. If this scheme can be implemented to these people, then this huge amount of system loss can be surmounted [75].
- It can be a cheap way to fully recharge the vehicle. Solar power recharge may cost approximately 50 tk. per charge.
- As there is no extra battery or auxiliary battery pack is required, initial investment will be cheaper than other types of solar power plan [76].

4.4.3 Challenges and Limitations

- Primary cost is huge for the owner of the fuel filling stations.
- Dearth of knowledge about clean renewable energy technologies.
- Dearth of consciousness of future improvement.
- Innight-time and in insufficient solar radiation the system will not work [77].

An example of successful solar-powered easy bike charging station was established in rooftop of Sunny filling station in Ruhitpur area in Keraniganj. Primarily the station has the provision and capacity to deliver charging facility to 20-22 easy bikes at a time. Easy bike owners will be primarily charged Tk. 50 per charging. Easy bike riders usually come to charge their vehicles at night. They are deliveredtotally charged batteries when they come; the batteries get charged by sunlight during the day [78].

4.4.4 Further recommendations

This is a crucial time for the Government of Bangladesh and IDCOL to make guidelines of phasing out 100% electricity based easy bikes by introducing:

- Charging station for battery charge which may run by solar power.
- Regular easy bikes can be modified to make hybrid solar powered vehicle.
- New types of vehicle should be introduced which will run by fully solar power.

Solar E Technology has advanced a demo version of solar passenger van & solar school van which is generally solar energy based [79].

Fig. 10 Recommended Solution for Overall Problem [79].

IV. Present Scenario and Prospects of Rooftop Solar in Bangladesh

Table 5. Rooftop solar in Bangladesh [26, 36, 58, 78]

Category	Present Scenario	Prospects
Off- grid and on-grid rooftop solar (SHS for residential buildings)	275 MW	1700 MW
Industrial & commercial rooftop solar	18 MW	600 MW
Government/semi govt. building's rooftop solar	1.6 MW	400 MW
Rooftop solar for solar powered battery charging station	20 kW	900 MW
Total	**294.62 MW**	**3600 MW**

Bangladesh is a developing country. Using all the potentials, it is pushing its economy towards the emerging market to turn into a developed one. To achieve the energy demand, a lot of long-time plans has been taken. By 2041 Bangladesh government has set a goal to produce 57,000 MW electricity, among them renewable sources will be 55% [80]. But it is unfortunate that till now Bangladesh is producing power only 3% by renewable sources whereas total generation is 21,419 MW, so it is very challenging for Bangladesh to fulfill the targets [81].

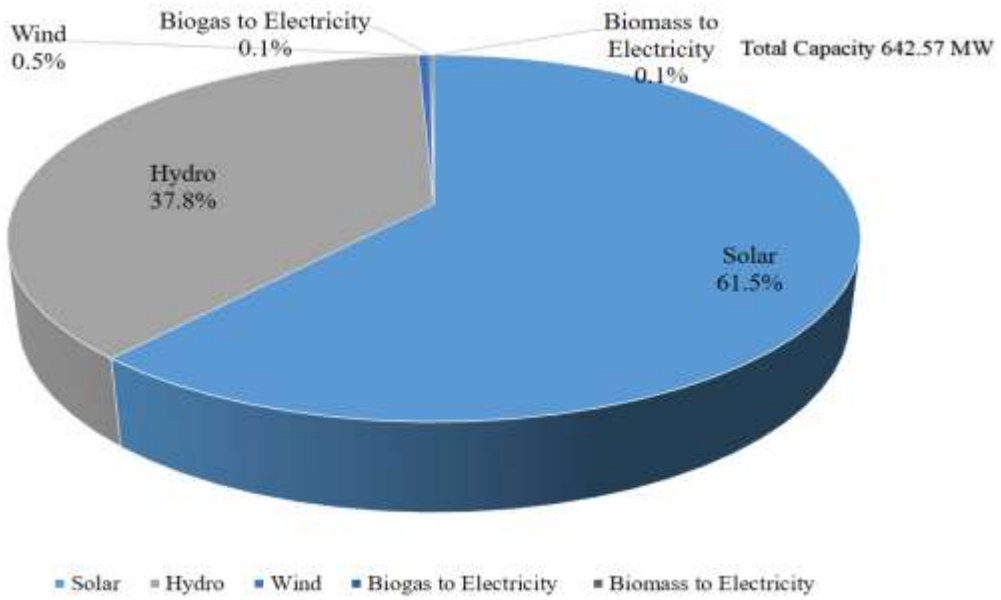

Fig. 11 Renewable energy share in Bangladesh [82].

As per the position of Bangladesh is not much suitable for the cases of wind power, bio-energy, hydro-power, biomass to electricity and biogas to electricity, so growth of renewable energy in Bangladesh will rely mainly on the development of solar power [83]. Due to limited land, rooftop solar is the best suitable alternative to produce desired amount of renewable power. So it should be taken into the account to meet the future renewable energy target and reduce the present power crisis in Bangladesh.

V. Conclusion

Sufficient electricity generation is very important to eliminate poverty, to ensure the standard quality of life and to enhance economic growth. Any kind of sustainable energy is embraced because of its low environmental impact. Solar power generation is considered to the best ecofriendly among all the sustainable energy. In Bangladesh there is plenty of space remains vacant on the rooftop of various buildings. By utilizing the space properly both off-grid and on-grid consumers can be benefited, and it will be helpful to control the power demand. By implementing solar powered battery charging station, it can reduce almost 900 MW of grid power consumption. However, more emphasis should be put on rooftop solar technology and proper use of its potential. Proper use of rooftop solar potential can reduce the present energy crisis in Bangladesh. Therefore, both the government and non-government organizations should take more initiative for implementation of rooftop based solar projects all over the country. Industrial power consumer canbe mostly benefited by the rooftop based solar projects because it is cheaper than the grid electricity. To motivate the industrialist and public agencies to adapt rooftop based solar technology, Bangladesh government already taken a plan to produce 300 MW of electricity by using the rooftops of factories and public agencies.

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