Prospects and Utilization of Solar Energy in Bangladesh

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Abstract—Power crises have become a major national problem in Bangladesh. Bangladesh is mainly dependent on fossil fuels for power generation, but fossil fuels will be depleted within a certain period of time due to its limited reserve. As a country of acute power crisis Bangladesh is now looking forward to develop its renewable energy sources in addition to its traditional sources of fossil fuels. Government of Bangladesh has already taken the initiative to produce 10 percent of total power generation from renewable sources by 2021 and increase it up to 20 percent by 2030. Solar energy is the largest source of renewable energy for Bangladesh. Bangladesh is such a country which bestowed with solar energy potential. If this energy is put to use, Bangladesh's energy problems will be greatly reduced. The generation of solar power will not only reduce the grid electricity but also fulfill the government's social commitment. In producing solar power, Bangladesh government is facing some serious problems, for example, acquiring land for solar park is the most crucial problem in Bangladesh. Because, Bangladesh being an agro-based country most of its land is used for agricultural purpose. In this paper we have discussed about the present scenario of solar energy, existing solar technologies and possible solutions to the problems that the government of Bangladesh is facing in producing solar power.

Index Terms— Agro-photovoltaics, concentrated solar power, solar boats and fish ponds, solar charging station, solar cold storage, solar drinking water, solar dryer, solar home system, solar irrigation, solar mini-grid, solar rooftop, solar water heater etc.

1 Introduction

As most available fossil fuel in Bangladesh is natural gas, gas dependent power generation is taking the lead on of total power generation in Bangladesh, whereas only 2.5% of power is generating from renewable sources (hydro, solar, biogas, biomass and wind). A large portion of generation, 97.5% of total power, is generating from burning fossil fuels which are polluting air, land, water and damages organic environment gradually. However, this scenario should be changed very soon otherwise our future generation would probably be in serious danger, experience severe harmful environmental effects, and may not stand before other countries. Renewable energy should be used as more as possible to ensure sustainable economic development [1]. Moreover, natural gas reserves are very limited in Bangladesh. According to Petro-Bangla (Nov 17, 2017) the remaining reserve of natural gas in Bangladesh is about 13 trillion cubic feet, the entire gas reserve to be exhausted in 8-9 years [2]. According to the Vision 2021, the government has set a target to produce 10 percent (2000 MW) of total power generation from renewable sources by 2021 and 20 percent by 2030 [3]. The prospect of wind power, bio-energy or hydro-power can be skipped considering their contribution in Bangladesh. Therefore, the growth of renewable energy in Bangladesh will rely mainly on the development of solar power [4]. To date installed capacity of solar power in the country stands at around 400 MW (2 percent) only [5]. With such a low level of development, it would be impractical to believe that the growth of solar power reaches anything near the projected target by 2021. However, proper use of solar energy technologies can help the government to reach the target. The widely known solar energy technologies are agro-photovoltaics, solar mini-grid, solar home system, solar irrigation, solar rooftop, solar charging station, solar water heater, solar drinking water, Solar dryer, solar boats and fish ponds, concentrated solar power. Among all those agro-photovoltaics, solar irrigation, solar rooftop, solar mini grid has the most potential prospects for Bangladesh. It is important to note that a number of limitations prevail in Bangladesh regarding the potential of solar energy. These include a) required land is not available; b) agricultural land can't be used for solar; c) flood prone area can't be used for solar; d) Bangladesh lacks of proper technology e) solar technology is expensive [6]. Solar energy is potentially viable field in Bangladesh. Solar energy can play an important rule to reduce power crisis in Bangladesh.

This paper reviews the present scenario and the prospect of several solar energy technologies in contrast of Bangladesh. The possible solutions which can solve the obstacles of producing solar power in the Bangladesh are also discussed in this study.

2 Potential of Solar Energy in Bangladesh

Bangladesh is endowed with reasonably good solar energy potential. The geographic location of Bangladesh is in between 20.30^0 and 26.38^0 north latitude. This is an ideal location having a total area of 1.49E+11 m^2 for solar energy generation. The average solar radiation is 5 kWh/m^2 that descend over the land for approximately 300 days per annum. Maximum solar radiation occurs during the months March to April and the

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minimum radiation occurs during the months 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, this huge amount of solar energy has a large potential which can be used in various sectors in Bangladesh [7].

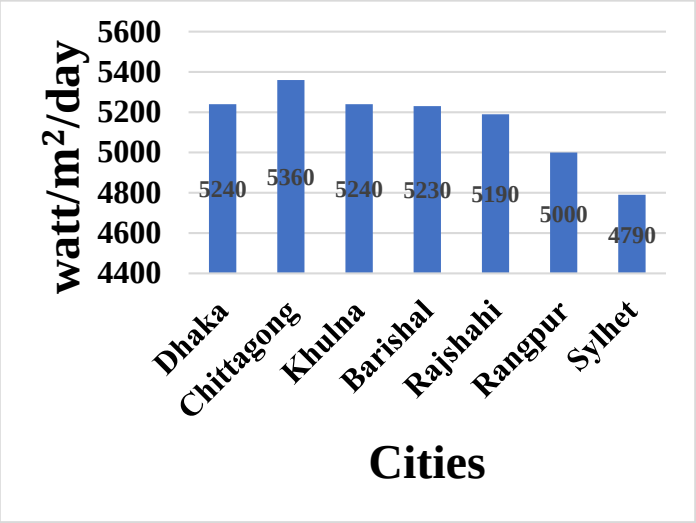

Fig. 1 Solar Irradiation in major cities of Bangladesh

The average solar irradiation in major cities of Bangladesh is higher than any other cities in Germany [8].

3 Solar with Agriculture (Agro-Photovoltaics)

There is a widespread conception that solar installments require the use of massive amount of land which would eventually reduce the land availability for agriculture production. Bangladesh government also disallows the use of agro-land for solar based installments. However, it is important to note that recent technologies allow both agriculture and solar based energy production at the same land by using solar-sharing technology. Though in general 4 acres of land is commonly observed to be used to produce 1 MW of electricity, recent studies have confirmed that the production of 1 MW of electricity might require as less as 2 acres of land. For instance, according to a research produced by Federal Ministry for Transport and Digital and infrastructure, as less as 1.7 acres of land could be used to produce 1 MW of electricity [9]. Combining solar panels with agriculture makes land more productive. According to Fraunhofer institute for solar energy dual use of system increased the total productivity of the land by 60 percent. From the perspective of agricultural science, agro-photovoltaics is a promising solution for increasing both the land use efficiency and the share of renewable energy provided by the agricultural sector [10]. Total agricultural land in Bangladesh is about 7.7 million ha [11]. On the other hand, 25% acquisition of land of Bangladesh remains unused or used in unproductive purposes [12], a large portion of the un-used state owned land in Bangladesh could be allocated for the use of solar based power generation. If this huge amount of agro-land can be used for solar sharing technology, it will turn a one of the most important solar energy potential for Bangladesh.

3.1 Solar Fishing Share Technology

There are an estimated 1.3 million fish ponds in Bangladesh, covering an area of 0.151 million ha, of which 55.30 percent is cultural, 28.52 percent is cultivable and 16.18 percent is unused [13]. Bangladesh is a riverine country. According to Bangladesh Water development board (BWDB) about 230 rivers currently flow through Bangladesh (during summer and winter), although the numbers stated are ambiguous in some sources. China has installed 200 MW solar park floats on top of a fish farm, located in Cixi, Zhejiang province [14]. Bangladesh government can adopt this technology for producing of solar power. Because, Bangladesh has lots of fish ponds as well as lots of unused riverside land. Using this technology, it can change the lifestyle of the people who live in riverside area, where there is no grid electricity.

4 Solar Mini-Grid

Bangladesh's population is very huge. About 80% people lives in rural and remote areas in Bangladesh where 42% people have no grid electricity [15]. In general, the demand for electricity in the rural areas of Bangladesh is comparatively low. There is a very small demand of electricity throughout the day. The use of electricity (mostly light, television, and fan) picks up only after the sunset [16]. To bring people of remote areas under access to electricity is a great challenge because it is difficult to extend the grid to remote areas and islands. Government of Bangladesh has initiated different programs and has given enormous efforts to bring mobility in rural economy. One of the initiatives is solar mini-grid in the off-grid areas. Solar PV based mini-grid projects are installed in remote areas of the country where possibility of grid expansion is remote in near future. 1078 off grid villages were initially identified by the Bangladesh Rural Electrification Board where there is no possibility to expand the grid electricity within the next 5-7 years. Under the supervision of SREDA (Sustainable and Renewable Energy Development Authority), potential villages will be electrified by solar mini-grid among these areas [17]. The solar mini grid projects are typically in the range of 100-200 kWp [18]. So far, 11 solar mini-grid with a cumulative capacity of 2.19 MW has been installed and are in operation. 15 more solar mini-grid projects are under implementation with a cumulative capacity of 3.17 MW. Majority of these projects are being financed by IDCOL (Infrastructure Development Company Ltd.) and they have a target to finance 61 more projects in the upcoming years. However, BPDB has installed 650 kWp solar mini-grid project at Shalla, Sunamganj which is the largest solar mini grid project in south Asia. Solar mini-grid will play a great role in bringing dynamism to rural economy [19].

5 Solar Home System

Bangladesh is among the five fastest growing economies in the

world. Keeping energy access reliable and on a low enough price to be affordable for everyone, has been a continuous struggle over the past decades. A decentralized renewable energy system presents a massive opportunity for Bangladesh to accelerate economic development, whilst improving energy access, livelihoods and the health of millions of people in a sustainable manner. In fact, over 5 million solar home systems (SHS) have been distributed in areas where electrification and grid expansion were particularly challenging. To date, the SHS has provided electricity services to over 11% of the population and has saved consumption of 1.14 million tons of kerosene for lighting, worth more than $400 million USD. Increasing access to electricity of rural people through solar home system (SHS) is becoming more popular day by day in Bangladesh [20]. The program has been acclaimed as one of the largest and the fastest growing off-grid renewable energy program in the world [21].

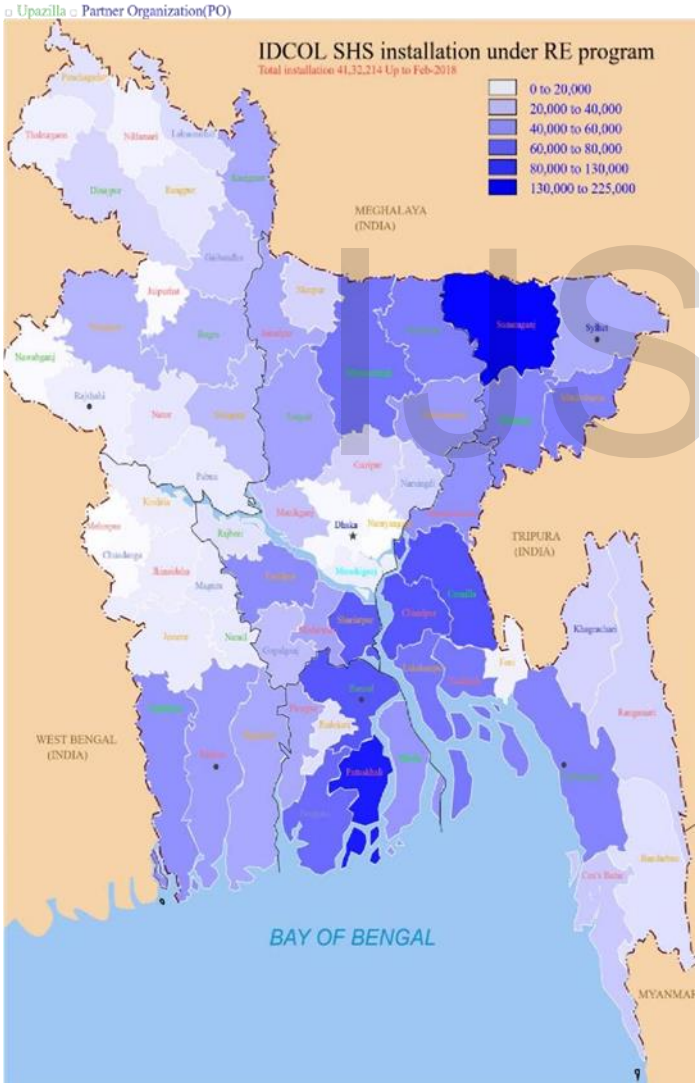

Fig. 2 IDCOL SHS installation in Bangladesh
Source: www.idcol.org/old/bd-map/ban

From Fig. 2, there remain lots of areas in Bangladesh where SHS and are not popular yet. SHS can play an important rule to develop the lifestyle of rural people.

6 Solar Irrigation

Irrigation problem is the most acute problem of Bangladesh being an agricultural country. About 3,36,000 pumps are used during dry seasons for irrigation purpose. About 50% people living in this country are off-grid and mostly use diesel generator for irrigation. People of on-grid use 1700 MW of power only for irrigation purpose, creating load shedding throughout the nation. Solar PV based irrigation is not a new concept and there are already a number of such irrigation schemes running in Bangladesh. Technologically, it is not a big challenge, as it does not require any highly sophisticated component. However, the main challenge comes from the actual cost of irrigation which is heavily dependent on the irrigation model in the context of the socio-economic condition of rural Bangladesh. As irrigation requirements are quite severe only during the dry months (3-4 months) the overhead cost becomes too high for dedicated irrigation projects [22]. Agriculture contribution to GDP is 18.64%. Approximately 64% of the total labor force in the country are involved with agriculture. 43% of Boro paddy production cost, especially for irrigation. Diesel-based irrigation system pollutes the environment by emitting excessive carbon dioxide while solar irrigation pump zero emission of CO_2 as alternate fuel sources will ensure the security of food. About 3.4 million ha of land need irrigation in dry season. So far, 999 solar irrigation pumps have been set up [23]. Government has a target to install/replace diesel operated pumps by solar pumps which will ensure 150 MW energy generations from irrigation sector.

- 1.61 million irrigation pumps (1.34 million diesels; 0.27 million electricity)
- Diesel irrigation pumps use approximately 1 million tons/year of diesel fuel ($900 million)
- Government spends $280 million per year to subsidize diesel fuel used for irrigation.

Total of 1426 solar irrigation pumps included in 14 projects

- IDCOL target of 1550 solar irrigation pumps, less 124 committed projects used as basis
- Projects grouped by administrative division and large and small pumps
- Two pump sizes selected from GPOBA material on Solar Irrigation in Bangladesh [24].

Table 1: Irrigation pump size

System Type	Solar PV Capacity
Large (Multiple Farmers) Pump	11 kWp
Small (Single Farmer) Pump	4 kWp

7 Solar Rooftop

About 48% & 31 % of total primary energy in Bangladesh are being consumed in the industrial & residential sector respectively. To ensure the energy efficiency in Bangladesh as a whole, it is necessary to ensure the energy efficiency of industrial and residential sectors first [25]. In Bangladesh most of the Roof-tops in the industrial and residential buildings are lying vacant either fully or partially [26]. Rooftop solar opens up new opportunities for industrial and residential consumers to utilize their idle roof spaces for sizeable solar power generation at ease with minimum maintenance, thereby reducing use of grid electricity. Approximately 100 square feet of roof space is needed for installation of one kilowatt peak (kWp) rooftop solar system. Since solar power has become cheaper compared to grid electricity for industrial consumers, using solar power reduces their electricity bills [27].

The following chart shows a comparative picture of rooftop areas in two urban hubs of Bangladesh and Germany.

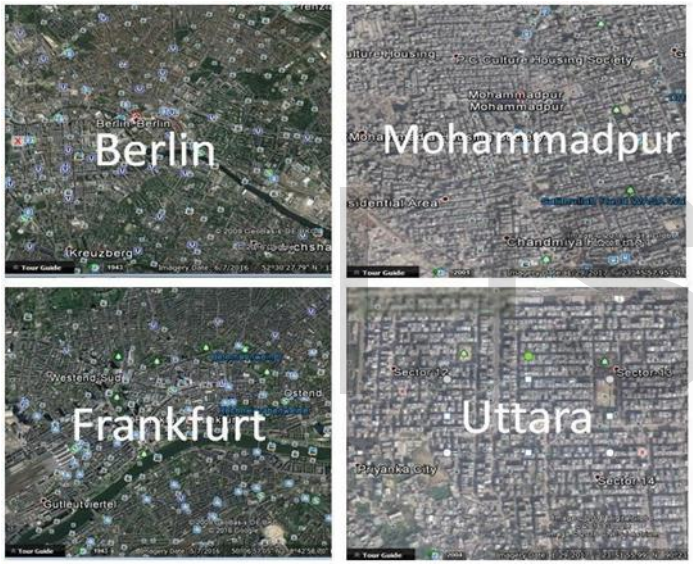

Fig. 3 Comparative Visuals of Urban Based Rooftop Solar Potential for Germany and Bangladesh

It is visually evident that urban cities in Bangladesh have more rooftop based solar potential compared to German cities. Unfortunately, no detail study has been done exploring the total rooftop potential in Bangladesh. We believe that the following measures should be taken to initiate and expand the installation of rooftop based solar projects. For instance:

- To identify the actual rooftop areas in the urban cities of Bangladesh
- To propose an appropriate financial incentive package for both commercial and household installations.
- To develop an appropriate infrastructure in order to supply rooftop-based surplus electricity to the national grid.
- To propose an appropriate tariff rate for both commercial and household clients [28].

Germany 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 percent. In Bangladesh "Industrial rooftops hold huge potential" Using rooftops of factories 1,000 MW of electricity can easily be generated. IDCOL estimates that Rooftops of major railway stations and junctions have potential to produce 45 MW of electricity. Workshops and small stations have potential to generate 55 MW of electricity [29]. 1,500 members of the Bangladesh Textile Mills Association have 42 million square feet of rooftop space, which could be used to install solar photo voltaic system with 400 MW capacity. According to the government's Power System Master Plan (PSMP), Bangladesh can generate 635 MW (17.3 per cent) from solar rooftop and the annual generation will be 860 GWh. As a result, around 576,200 tons of CO_2 emission will be reduced. Till October 2019, around 62 off-grid roof-top solar projects with generation capacity of 14.36 MW and 50 on-grid projects with generation capacity of 26.45 MW have been completed and are now run by public and private sectors. According to a study conducted by IFC (International Finance Corporation), with rooftop solar, factories could reduce grid power consumption by 5 to 20 per cent. IFC said that opportunities for renewable energy solutions in Bangladesh textile sector, the rooftop Solar PV potential across the Bangladesh textile industries will be 109 MW for on-grid replacement which will subsequently reduce 98591 tons of CO_2 emission [30]. Declining costs of solar power together with net metering scheme has created an enabling environment for industrial consumers to monetize unutilized roof space through installation of rooftop solar. Taking advantage of this conducive environment, few industrial consumers came forward to install rooftop solar system. For example, Paragon Poultry Limited (PPL), located in Gazipur district near the Dhaka-Mymensingh highway, installed a 723.06 kWp with an AC capacity of 670 kW solar PV system on top of poultry sheds and Far East Spinning Industries Ltd (FESIL), located in Habiganj district near the Dhaka-Sylhet highway, installed a 1.1 MWp with an AC capacity of 1 MW solar PV system utilizing both rooftop and empty ground spaces. In view of scarcity of land, rooftop solar offers a feasible application to scale up solar power generation in Bangladesh [31].

8 Solar Water Heater

The demand of hot water in Bangladesh is increasing day by day as the country is becoming more dependent on industrial sector. About 500 gallons of hot water are needed daily in the tanneries and in pharmaceuticals only. Glass, Ceramic and other factories also need hot water for their production. Beside it has been now a great necessity of hot water supply in the hospitals, hotels. Today all these hot waters are coming from either electric or gas-based water heating system. This leads to a lot of consumption of limited resources. It also creates pressure on the power generation. To reduce the pressure on the power sector where Bangladesh already have a lot of crisis,

need an alternative water heating system that provides continuous hot water supply without consumption of electricity. The Alternative Solar hot water system is just the solution the Bangladesh government is looking for [32]. It is simply an energy efficient technology. It is low operating and maintenance cost will cover the huge initial fixed cost. So, in the long run it will be cost-effective as the average cost of solar heater will eventually fall down. Not only that, solar water heaters are beneficial in terms of saving as well and it could reduce electricity bill up to 60-80%. Although there are many benefits of solar water heater, Bangladesh is still lagging behind in adopting it. On the other hand, neighboring country India is far ahead of Bangladesh in adapting to renewable energy technologies, to heat water, and it currently accounts for about 33% of India's primary energy consumptions [33]. Industries using boilers can save their energy expenses significantly, by using solar hot water solutions for pre-heating boiler-feed to about 65^0 C. Hotels can save significantly by using solar hot water solutions for bathing and cooking requirements. Solar thermal systems can pay back in 3-4 years, which is much quicker than PV systems. A new 20-liter storage water heater consumes 2 units of electricity per hour, while an instant water heater consumes 3 units per hour. So, a family of 4 can save up to 90 units of electricity per month, by using a solar water heater [34].

9 Solar Charging Station

Currently two types of electrical vehicles are running in Bangladesh. One is locally called "easy bike". The second one is two seated rickshaws. Both of them are energy efficient and environment friendly being popular in the world as well as Bangladesh.

Fig. 4 Two types of electric vehicles in Bangladesh

There are approximately 900,000 easy bikes in Bangladesh which operate on battery power. Batteries are currently charged through main supply electricity, consuming more than 400 MW of electricity per day. At present the easy-bikes are being charged from household connections, putting extra pressure on the national grid. Most easy-bikes charge their batteries by connecting illegally to the power grid, depriving the government of a large amount of revenue.

Opportunities and Benefits of Solar charging station:

- 300 MW to 500 MW power was used every day to recharge the easy-bikes and in most cases, it was done illegally. Using this theme this problem can overcome.
- Recharging an eclectic vehicle will cost maximum 32-40 taka.
- Investment is lesser than other solar project because of not using inverter circuit and Battery Bank.

Challenges and Limitations of solar charging station:

- Initial cost is high for the owner of the fuel filling stations.
- Lack of knowledge about clean renewable energy technologies.
- Lack of awareness of future development.
- During night-time and in insufficient solar radiation the system will not work [35].

A solar-powered easy bike charging station is established in rooftop of Sunny filling station in Ruhitpur area in Keraniganj. Initially the station has the provision and capacity to provide charging facility to 20-22 easy bikes at a time. Easy bike owners will be initially charged Tk. 50 per charging. Easy bike riders usually come to charge their vehicles at night. They are provided fully charged batteries when they come; the batteries get charged by sunlight during the day [36].

10 Solar Boats and Fish Pond Aerators

Solar Boats:

- Solar PV can be used to provide social services to rural communities.
- Shidhulai-Swanirvar-Sangstha has used solar PV technology to provide electric power on a fleet of 111 boats that serve as: Health clinics, Schools, Libraries, Adult education centers.

Solar fish ponds:

- An estimated 1.3 million fish ponds in Bangladesh use diesel and electric pumps to aerate.
- PV-powered aeration systems are seen as a possible alternative to existing diesel pumps.
- Low utilization rate of pumps (2-3 hours daily) potentially hurts financial viability [37].

11 Solar Drinking Water System

Solar powered drinking water dispensing systems are now providing drinking water in rural areas in the southern part of Bangladesh. Solar drinking water systems, including filtration systems, arsenic free systems can be popularized in order to ensure safe water supply eliminate arsenic, salinity and other wastes from water. Meanwhile, 152 (1.5 MW) solar drinking

water systems have been established in the coastal areas in Bangladesh. German financial assistance under the SED program helped to set several pumps in 12 districts of Bagerhat, Barguna, Khulna, Pirojpur, Satkhira and Gopalganj which is in the process of transfer to the Department of Public Health Engineering under the REEP (Renewable Energy and Energy Efficiency Program) project [38].

12 Concentrated Solar Power (CSP)

CSP is a promising technology for power generation in which the solar radiation is concentrated to generate high temperature for producing steam in a solar thermal power plant. No fossil fuel is used in this technology; therefore, no greenhouse gases are emitted. With an average annual Direct Normal Irradiance (DNI) of 2,000kWh/m^2 the area required to generate 100 MWe of electricity is about 2km^2. Bangladesh receives an average annual DNI of nearly 1,900kWh/m2 which is sufficient to operate a CSP plant. As there is no fuel cost in CSP, this can be an attractive choice to mitigate the power crisis of Bangladesh [39]. The CSP technology mainly includes four alternatives namely parabolic trough, solar tower, linear Fresnel, and parabolic dish [40].

12.1 Solar Cooking

Cooking is one of the major energy consumption sectors in Bangladesh where mainly non-renewable sources (i.e. firewood, natural gas, LPG etc.) are used. A solar cooker is a device that uses sunlight to produce heat in order to cook food. Solar cooking is the cleanest and safest mode of cooking. It utilizes solar energy which is abundantly available in nature to cook food. There are three major types of solar cookers:

a. Box-type solar cooker:

The box cooker is one of the most widely used solar cooker types. It consists of a well-insulated box with a transparent lid, usually made of glass or plastic. The lids are sometimes glazed and additional reflectors are used so as to increase the incident radiation and, at the same time, decrease the heat loss into the surrounding air. Food is kept in a black (or very dark) cooking pot and placed inside the box cooker. The box cooker uses the principle of greenhouse effect to cook the food contained in it.

b. Panel-Type Solar Cooker:

A panel-type solar cooker is a very simple and inexpensive form of solar cooker. It uses reflective panels to direct sunlight towards a transparent, plastic bag containing the cooking vessel (painted black). It uses the same heat trapping principle as the box cooker, except that instead of a box, the cooking vessel is kept in a tightly closed transparent bag. A panel cooker relies on focusing sunlight towards the transparent bag by using multifaceted reflective panels.

c. Parabolic Reflector Solar Cooker:

The parabolic reflector solar cooker uses reflective metal sheets and/or lenses to cook food. It uses the principle of concentrating optics and needs to be properly aligned to follow sun's motion in the sky from time to time. The concentrated sun's rays must be exactly directed at the position where the cooking vessel is kept.

Advantages of solar cooking:

There are several advantages of implementing a countrywide solar cooking practice:

- **Reduction of Deforestation**: In Bangladesh, 40 million tons of firewood are burnt for cooking causing air pollution. Solar cooking neither produces smoke nor involves cutting down of trees.
- **Reduction of GHG (Green House Gas) emission:** By burning 1000kg of firewood, 1900g of carbon dioxide gas is released into the atmosphere. Burning of 1000 cubic feet of natural gas produces 55,622.38 g of carbon dioxide. But Solar cooking does not emit any GHG.
- **Gas Crisis Mitigation:** The total number of gas connections is 23, 25,456 If such a household uses a solar cooker on every sunny day, it is possible for that household to save about 94.49×145=13,701 cubic feet of natural gas per annum.
- **Health issues and safety reasons:** Burning firewood or Combustion of gas releases nitrogen dioxide, Sulphur dioxide and also formaldehyde, which, if inhaled over a long period of time, results in asthma, wheeze and even lung cancer. Occasional accidents also led to fatal consequences.

Potential of solar cooking in Bangladesh:

There are on average 294 and 145 days in a year of Bangladesh when the global horizontal radiation and the direct normal radiations respectively are above 4.0 KWh/m^2. Solar cookers mainly depend on direct radiation, although box cookers make use of both direct and diffused radiations. Hence, on average, solar cookers can be used on 145 days per annum.

Obstacles of solar cooking:

There are several obstacles to successful deployment of solar cookers over a countrywide range. The obstacles are discussed below:

- **Lack of flexibility:** Solar cooking can be done only in the presence of sun and with necessary solar insolation. Moreover; solar cooing takes longer to cook food than conventional methods.
- **Limited Access to Sunlight:** Although rural people in Bangladesh may still get plenty of sunlight for cooking,

very few residents of the city area have access to sunlight for solar cooking purpose [41].

12.2 Parabolic Dish

It similar in appearance to a large satellite dishes, but has mirror like reflectors and absorber the focal point. It used a dual axial sun tracking. It is efficiency of 30% achieved. By this dish it produces in MW level in solar plant. This is highest conversion performance of the concentrating solar power technology.

12.3 Fresnel

In a Fresnel lens, the refraction happens to produce in the surface, while the large material between the two surfaces doesn't have any problems in the refraction. It will use raise more temperature than conventional one and also used in furnace heating. Its installation has been used for surface modifications of metallic materials. This equipment is applying solar energy in the field of high and very high temperatures. These temperatures are achieved in a few seconds. Fresnel concentrator performed 34.3% reduction in reflective area compared to a parabolic of the same diameter, the 20 minutes' series of action performance needed for manual adjustment in order to track the sun proved to be a major disadvantage with this device. Cox's Bazar is the best place for installed Fresnel reflector solar plant in Bangladesh due to its geographic location.

12.4 Parabolic Trough

It contains of linear parabolic reflector concentrates light onto a receiver positioned along the reflector's focal line. It consists of receiver is a tube positioned directly above the middle of the parabolic mirror and fluid with a working fluid. A working fluid is heated 150-350 ^{0}C as it flows though the receiver is then used as heat source for a power generation system [42]. Glass and steel are the main materials for parabolic trough power plant. Bangladesh has currently become self-sufficient in glass production; even glasses are now also being exported to many countries. Furthermore, nearly 250 steel re-rolling mills are manufacturing steels in the country. If domestic glass and steel are used to construct the solar field of the parabolic trough power plant, the plant can be erected with much less capital investment. Therefore, for large scale production, parabolic trough technology can be implemented in rural areas of Bangladesh [43].

13 Solar Dryer

Almost 20% of farmers produce in Bangladesh, including potato, tomato, pies, and onions are damaged due to heavy moisture. This could be easily prevented through the solar drying system. It is possible to save about 20% of the crop if the process of solar based 'crop drying' is implemented [44]. Energy consumption in drying food products is increasing day by day. Therefore, for reduction of energy consumption, it is required to bring the solar energy technology in picture. For preservation of the agricultural products, mostly open sun drying technology is used in Bangladesh. Bangladesh have been facing food problem, due to population explosion which eventually has created an imbalance in food distribution. These days, poor storage techniques degrade the quality and quantity of food products. However, it is also impossible for farmers to increase production of food with decreasing availability of land to solve this problem. Therefore, storage of food grain through drying is a major channel in terms of safety and security of food items. Still now open sun drying is mostly used to dry food grains, fruits, leafy vegetable and spices in Bangladesh. The major advantage of such drying technique is their storage for long terms but degradation in the quality of food besides time consuming is an issue. Now days, there are different type of solar dryer technology are used for drying that are open sun drying greenhouse dryer direct solar dryer, indirect solar dryer, mixed mode solar dryer, dryer with thermal energy storage, natural convection and forced convection dryer. Indirect and tunnel dryer are very much convenient as the product are not good under direct solar radiation and better controlled condition. There are number of factors that affect solar drying process solar irradiance and temperature, performance of solar collector, effect of air velocity etc. Thermal energy storage system also used with new design solar dryer which help to raise the temperature range and time duration for drying. But these technologies increase the initial investment. So that this system is much useful for industrial purpose but not much effectively used by farmer. Indirect solar tunnel dryer has most potential prospects for Bangladesh [45].

14 Solar Cold Storage

In the absence of adequate cold storages in Bangladesh, farmers are forced to sell their crops and vegetables at a low price. Due to frequent power cuts in the rural areas, solar based cold storages are specifically suitable for farming villages [46]. In the global climatic zones, Bangladesh is a tropical country where average daytime temperature ranges between 23^0 C to 34^0 C. Seasonal vegetables and fruits require storage refrigerated warehouse facilities (called as "Cold Storage"). Most vegetables and fruits are preserved at variable temperature between 30^0 C to 50^0 C for marketing off- seasons at a higher price in major urban markets. In traditional business culture, "Cold Storage" is assumed as a large size (2,000-5,000) tons of Potato storage only with huge investment, high electricity bills, and also unpredictable profit or loss due to unreliable power supply frequent load shedding. The irregular supply of grid electricity is a major problem faced by cold storage owners. As a temporary solution, cold storage owners invest for costly standby generator which is unreliable and hazardous too. Therefore, small farmers are discouraged to invest in cold

storage by banks and other lenders until pilot projects demonstrate success. As power outage becomes more frequent in the summer when cold storages have to operate in pick load, the owners, operators and clients suffer heavy financial loss. This also affects other businesses, employees and the national economy as well. In Bangladesh alone, the primary producers, and retailers suffer a loss and damage up to 60 percent of seasonal fruits, vegetables, fish, milk and meat items which accounted for Tk. 3,442 crores (BBS, 2011). To minimize loss and maximize profits, both the existing and future cold storage owners are actively seeking "mini solar cold storage (of average 8-10 tons' capacity)" as the best alternative sources of dependable, sustainable, cost effective and environment friendly sources of power. Solar powered mini cold storage has become exciting innovative technology among farmers both in on-grid and off-grid areas of Bangladesh. To turn loss and damage into profit, the Government of Bangladesh encourages dissemination of mini cold storage with solar and other alternative power back through SREDA [47].

15 Some Solar Technology

When we think of solar panels, chances are we think of roofs or giant arrays of glimmering panels in the desert. However, advances in photovoltaic (PV) technologies over the last decade have made possible many smaller-scale applications for everyday living, on a more person al level. We mention here some innovative, low-cost solar technology that are not common in Bangladesh and these technologies is being used to enhance people daily lives.

15.1 Cell-Phone Charger

USB cell phone chargers can charge a phone to almost full after only a few hours' exposure to UV sunlight. These portable solar panels are about the size of a tablet and can also charge GPS trackers, tablets, or even laptops. They can be hooked on backpacks to collect solar energy as you walk, making them ideal for outdoor excursions.

15.2 Solar Backpacks

Thin-film solar panels attached to the outside of backpacks provide up to about four watts of power— enough to charge phones, cameras, and other devices while simply walking. These exterior solar cells can also be attached to briefcases and handbags. These backpacks are ideal for students, hikers, and campers, who will always have a charged device during their travels, or when they reach their destination.

15.3 Solar Fabric

Solar fabric is an application of solar technology with a wide range of applications. Solar cells are woven into textile fibers and generate convenient solar electricity. One version, created by FTL Solar, can literally be pitched like a tent to provide both shelter and electricity. Consider the endless possibilities: military, rescue operations, disaster relief, recreational options, medical units, and even temporary housing. Any place you need flexible convenient solar power; solar fabric is your answer.

15.4 Bike Locks

The Ellipse Skylock is the world's first solar-powered bike lock. It powered by a built-in solar panel that provides enough power for a week after just one hour of charging. The Skylock connects wirelessly to the rider 's phone to provide keyless entry, theft detection, bike sharing, and crash alerts. It also sends an alert if the bike is disturbed, using its long-range Bluetooth.

15.5 Vaccine Refrigerator

In developing countries, 24-hour electricity is not guaranteed, and in many cases, there is no electrical grid. Private companies have been manufacturing solar powered vaccine refrigerators so healthcare workers in remote areas can administer critical medication to those who need it [48]. 6 sets solar PV Vaccine Refrigerators for the Health Care Centers of 360 W of each has been installed in Rangamati district, Bangladesh [49].

15.6 Solar Paint

Solar paint, also known as photovoltaic paint, is exactly what it sounds like. It's a paint that anyone can apply to any surface that will capture energy from the sun and transform it into electricity. It is actually three different technologies combined into one. The first, solar paint hydrogen, works by absorbing moisture from the air and using solar energy to break the water molecules down into hydrogen and oxygen [50].

15.7 Solar Tents

Solar powered tents are traditional tents with a tech twist. Equipped with a solar panel, these tents allow to charge all small electronic devices (mobile phones, tablets, laptops, cameras, speakers, and mp3 players). The U.S. Army has a version that can generate up to 2 kilowatts of power a day [51].

Conclusion

Falling costs, driven by technological advances and economies of scale in manufacturing, have increasingly been making solar energy as competitive as conventional energy. Proper use of solar energy technologies can greatly reduce the dependence on conventional energy of Bangladesh. Still, solar share in Bangladesh energy sector is very low. But, it is possible to make a solar revolution in Bangladesh. Solar home system is an

example of it. It is one of the fastest growing off-grid renewables programs in the world. Solar technologies discussed above can help Bangladesh government to reduce irrigation problem, load shedding problem, water heating problem, cold storage problem, easy bike charging problem, agricultural products drying problem, acquiring land for solar park problem, rural people electricity problem and many more by producing more power. So, it is high time for Bangladesh government to take proper steps to producing more and more power by using solar energy technologies.

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