Chapter 11
Supplementing Electrical Power Through Solar PV Systems

Md. Humayun Kabir and Wilfried Endlicher

Abstract Dhaka megacity is home to more than 14 million inhabitants. However, the adequate supply of urban utilities, particularly electricity to city dwellers, has been a major challenge mainly due to high population pressure and increasing demand. An insufficient supply of electricity (1,000–1,200 MW) compared to its peak demand (around 2,000 MW) has had a severe negative impact on the city dwellers' lifestyles. Given the shortfall of power supply in Dhaka, electricity generation through rooftop solar PV systems is widely discussed nowadays. Based on secondary data (sunshine duration, GHI values, etc.) and literature (identification of well-illuminated rooftops within the city and calculation of solar PV-based electricity generation potential by the authors), this chapter reveals that the driving forces (geophysical, economic and sociopolitical and environmental factors) are fully supportive of harnessing solar energy for electricity generation. The application of solar PV system on the city's extensive well-illuminated rooftops (>10 km^2) would be very effective and could possibly meet around half of the city's power demand.

Keywords Bangladesh • Dhaka megacity • Driving forces • Power supplement • Solar PV systems

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11.1 Introduction

Bangladesh has been experiencing a severe power deficit for the last few decades due to rapid population growth. Both per capita generation and consumption of electrical power are extremely low as compared to the global and neighbouring country rates (Akbar 2004). As at 2011, only around 40 % of the total population is serviced by public utility grids. Although the country's electricity demand has increased enormously over time, it has not been possible to enhance the installed generating capacity for various reasons. A drastic decline in the reserves of indigenous gas, which contributes more than 80 % of the country's electricity generation, has recently created immense interruption in electricity generation and supply. The annual per capita generation and consumption of electricity, both less than 200 kWh in 2011, are among the lowest on the globe, meaning that the country is a land of power crises. Although the installed capacity of electricity generation in Bangladesh accounts for nearly 7,000 MW (as of 2011), only around 4,000–5,000 MW can be regularly generated (BPDB 2009, 2011). Moreover, electricity is currently generated mostly with conventional fuel sources (82 % indigenous natural gas, 9 % imported oil, 5 % coal and 4 % hydropower) (2011 figures), whilst the rapid decline in natural gas reserve has already started hampering electricity generation in the country. In contrast, the megacity of Dhaka, from the viewpoint of social, economic, political, education, health and other services, is of immense importance to the nation, and its central location has further enhanced its significance to the people. But the city struggles to provide adequate urban utilities (particularly electricity supply) to city dwellers which has recently been a major challenge to development authorities mainly due to immense population pressure and increasing demand. Insufficient supply of electricity to the city (1,000–1,200 MW) compared to its peak demand (2,000 MW) has acutely aggravated the lifestyles of the city dwellers. Given the severe deficiency of electrical power, there is a crying need to supplement electricity from renewable sources. As a precondition of being connected with public utility grid in Dhaka, newly constructed buildings in the city must be able to provide at least 3 % of the electricity demand from solar PV systems. Considering the abundance of suitable sites on well-illuminated rooftops and the effectiveness of solar PV systems, their application is shown to be a viable and pragmatic option for providing electricity supplement to the present capacity (Kabir and Endlicher 2012; Kabir et al. 2010). The successful application of solar PV systems requires an in-depth assessment of the driving forces, which include geophysical (absolute location, global horizontal irradiance, temperature, cloud cover, sunshine duration, land availability and so on), economic and sociopolitical (capital investment, technology supports, social acceptability, political commitment, etc.) and environmental factors (climate protection through GHG emission reduction). An assessment of these driving forces reveals that the application of solar PV system can substantially meet the city's power demand. The present chapter, based mainly on secondary data (sunshine duration, GHI values, etc.) and published materials (e.g. Kabir et al. 2010; Kabir and Endlicher 2012), is an attempt to assess the role of the driving forces in harnessing solar energy resource for electricity supplement in Dhaka. The objective of this chapter is to assess the role of the driving forces of solar photovoltaic applications in the megacity of Dhaka. Specifically, this chapter identifies electricity generation potential from solar PV systems through rooftop installations.

11.2 Materials and Methods

This chapter is primarily based on secondary data and published literature. Secondary data on global horizontal irradiance (GHI), sunshine duration, etc. were collected from the Renewable Energy Research Centre (RERC) of the University of Dhaka. GHI data from 2003 to 2007 of various cities of Bangladesh including Dhaka have been prepared by the RERC with the financial support of UNEP and GEF under the Solar and Wind Energy Resource Assessment (SWERA) Project. Kabir et al. (2010) and Kabir (2011) identified well-illuminated rooftops in Dhaka through object-based image analysis (OBIA) from high-resolution (60 cm) Quickbird satellite data of 2006 that covered an area of 431 km^2. Along with solar data, published literature has (mainly by the authors and others) widely been reviewed.

11.3 Power Supply Scenario

With the dramatic growth of the city population, the demand for energy has also been increasing. Whilst the city receives priority supplies of electricity at the expense of other parts of the country, the overall situation is not satisfactory at all. The whole system of electricity distribution is poorly managed and also suffers losses of more than 30 % of the system due to illegal connections (Alam et al. 2004). There have been a number of attempts at reform of the power sector in the country, aimed at reducing system loss, but practically all these reforms have been inconsequential. The first serious attempts at power sector reforms began shortly after the country achieved independence in 1971. In 1972, the Bangladesh Power Development Board (BWDB) was created to ensure satisfactory power supply to feed the newborn country's socio-economic development. Major initiatives include the establishment of the Rural Electrification Board (REB) in 1977, the Dhaka Electricity Supply Authority (DESA) in 1991 and the Dhaka Electric Supply Company (DESCO) in 1997 (Alam et al. 2004). Although DESA initially took over Dhaka District for power supply under the control of BPDB, it has gradually reduced its jurisdiction, handing over the rural areas to REB, and now has been confined to Dhaka megacity (except for a part of the metropolitan area). DESCO, wholly owned by DESA, is responsible for all activities of distribution system in Mirpur, Uttara, Gulshan and its adjoining area under the Company Act. Dhaka

Power Distribution Company (DPDC) was created in 2005 through recent power sector reforms under the Company Act 1994, which is responsible mainly for the southern part of Dhaka City and for the adjacent towns of Narayanganj and Tongi. In Bangladesh, power generation is performed by BPDB, REB and Independent Power Producers (IPPs), whilst distribution is run by BPDB (29 %), REB (12 %) and DESA (59 %). BPDB and Power Grid Company of Bangladesh Limited (PGCB) are the agencies responsible for power transmission in the country.

The electricity demand of Dhaka megacity is increasing at an alarming rate every year due to the rapid growth of population along with the growth of electricity connectivity. Currently, the demand is around 1,500–1,700 MW, but DESA can supply a maximum of 1,000–1,200 MW, which is not adequate to the existing demand. The situation becomes acute in the summer, when the demand of electricity increases to about 2,000 MW. The reasons for this worsening situation in the power supply of the megacity primarily lie with wide-scale corruption of stakeholders, mismanagement or undesirable system loss, ageing of the infrastructure and unpredictable annual increase of demand. The unexpected demand is mainly due to the installation of luxury goods like air conditioner in shopping centres, private universities, commercial office buildings, clinics and hospitals, as well as some public buildings, which lead to the huge increase in electricity demand during the summer. The supply often fails to meet the demand and has led to events such as riots against the electricity providers. In the last few years, the impatience of the city dwellers has risen, and several people were killed in riots over electricity, particularly in 2006. This situation was brought about by load shedding caused by the tremendous shortfall of electricity, particularly in summer when the daily shortfall is around 500–800 MW. In order to minimise the adverse situation, various strategies have adopted by the responsible agencies. The former Caretaker Government (January 2007 to January 2009) prepared a renewable energy policy which is yet to be approved by the Parliament. The sitting government (since 2009) has imposed the obligations that newly constructed buildings must be able to provide at least a 3 % supplement of electricity demand from solar PV systems as a precondition of being connected with public utility grid.

11.4 Solar PV in Bangladesh: Current Installations

Solar PV systems installed in Bangladesh so far are mainly solar home systems (SHS) in off-grid areas where electricity supply through public grids is not feasible and would not be possible in the near future. In contrast, Grameen Shakti (GS) has a target of installing ten million SHS by 2015 which will cover approximately 10 % of the rural people (Barua 2007). At the end of 2011, the installed capacity of solar PV systems (stand-alone) with one million solar home systems all over the country accounted for nearly 50 MW, an increase from 15 MW in 2008. It is assumed that this installation process will continue until the entire country gets connected to public utility grids. The electricity demand in the rural areas is still confined to lighting, using black-and-white television, mobile phone charger and other low-consumption appliances.

In spite of massive power deficit in the megacity of Dhaka, no substantial action has been undertaken to promote large-scale photovoltaic applications except several small-scale rooftop installations (e.g. a pilot project 1.5 kWp grid-connected PV system at University of Dhaka (2007), 10.16 kWp system at the prime minister's office).

11.5 Determining Factors of SPV Application

Considering the abundance and effectiveness of renewable sources, the exploitation of solar energy for electricity generation in Dhaka megacity is the most attractive option (Kabir and Endlicher 2012). However, three major groups of factors (physical, geographical and technical) are essential in order to assess the effectiveness and potential of solar PV systems in a particular area (Izquierdo et al. 2008). In the case of Dhaka, a number of other factors can also be considered as the determining forces. These factors include geophysical, economic and sociopolitical aspects. The geographical location of the site, land availability or available surface area (available roof area of buildings in the built-up areas), global horizontal irradiation (GHI), sunshine hours, temperature, cloud cover, etc. are categorised as geophysical factors. Economic, technical and sociopolitical factors are equally as important as the geophysical viability. Economic and technical aspects include financial arrangements, technology support, performance of the systems and availability of local skilled technicians to maintain the systems. Social factors include consumers' acceptance and willingness to pay for SPV-based electricity technology, whilst political factors include the government's commitment and good governance. Last but not the least, environmental aspects are important and include greenhouse gas emission reduction, ensuring clean environment and protection of climate. The environmental issues can be viewed as the nation's obligation that can be achieved through the exploitation of renewable energy sources.

Geophysical Factors

Geophysical situation of an area is the most important determinant for the consideration of SPV applications. In the present chapter, the geographical location of Dhaka on the globe, space availability (land availability, available roof surface, etc.), sunshine hours, global horizontal irradiance (GHI), etc. have been identified as the main geophysical factors. Based on the suitability of the geophysical situation, other associated factors need to be assessed. If the geophysical state is not supportive to the PV applications, further assessment of other aspects will be futile. An assessment of these factors has been made in the following sections to investigate whether the data on these geophysical factors are supportive of solar PV applications in Dhaka megacity.

Sunshine Hours and Solar Radiation

Sunshine duration, global horizontal irradiance (GHI), cloud cover, temperature, etc. are the most important geophysical factors which influence the energy potential from the applications of solar PV systems. Sunshine duration at the proposed location of an installation is crucially important. The aggregate GHI depends on how long the site receives sunlight. From a solar energy generation perspectives, Bangladesh is located in a global position that offers very satisfactory sunshine duration. Long-term (1988–1997) sunshine data recorded by the Renewable Energy Research Centre of the University of Dhaka reveal that the period from November to May has the maximum sunshine duration and the period from September to October is reasonably satisfactory (SWERA/RERC 2007). The maximum daily mean sunshine hours in Dhaka occur in February (9.1 h), with the minimum daily average being in June (4.9 h). Although the day length remains quite high in June, the sky is overcast most of the time. As a result, direct sunshine hours remain lower for the receipt of solar irradiation. The daily maximum peak sunshine hour also occurs in February (10.7 h). The daily average sunshine recorded in Dhaka is 7.55 h, and nearly 2,800 h of sunshine is received annually. For comparison, the sunshine exposure of the best global locations (in the Sahara desert and a few countries of the Middle East) is around 4,000 h per year. Algeria, located in the northern part of Africa, is a country of high insolation with 3,300 h of bright sunshine annually (Chegaar and Chibani 2000). Therefore, in comparison with the countries of high duration of incoming solar radiation, the sunshine hours of Dhaka seem quite satisfactory.

Due to the availability of sunshine throughout the year, the GHI of Bangladesh is also satisfactory for generating sufficient solar energy. The daily average GHI in Bangladesh is 4.29 kWh/m^2 and the annual estimation is 1,566 kWh/m^2. It has also been determined that on horizontal and tilted surfaces, the average annual availability of solar radiation in Dhaka is 1.73 MWh/m^2 and 1.86 MWh/m^2, respectively (Hussain and Badr 2005). The RERC of the University of Dhaka, with the financial support of United Nations Environment Programme (UNEP) and Global Environmental Facility (GEF), started the 'Solar and Wind Energy Resource Assessment (SWERA)' project in 2003 and produced reliable data on GHI and diffused normal irradiance (DNI) for Dhaka City and other parts of the country. The centre has also acquired GHI measurements for two time periods (1987–1989 and 1992). The maximum amount of radiation is available in the months of April–May (>4.5 kWh/m^2), and the periods from February to March and June to August also provide excellent solar radiation (~4.0 kWh/m^2). The rest of the months in a year still receive a reasonable amount of GHI (just less than 4.0 kWh/m^2/day). During the SWERA project, the RERC recorded hourly basis GHI data from January 2003 to December 2005. The highest hourly GHI (764 Wh/m^2) is received at 12:30 in April and GHI 727 Wh/m^2 at 11:30 in May (SWERA/RERC 2007). The daily aggregate GHI recorded in Dhaka in April and May is 5,286 Wh/m^2 and 5,459 Wh/m^2, respectively. Moreover, the daily total GHI received in March appears also to be excellent (4,884 Wh/m^2) (SWERA/RERC 2007).

Land Availability

Land use of a city provides a good indication of the city planning. In a well-planned city, a suitable proportionate ratio among various uses of land is found. For various reasons this is generally not seen in the cities of developing countries. Dhaka is an example of such city which has experienced very irregular development, leaving very negligible open spaces (below 5 %). Dewan and Yamaguchi (2009a, b) reported in a study of land use in Dhaka metropolitan area (DMA) in 2005 that built-up areas occupied 49.4 % (205 km^2) of total metropolitan area (416 km^2). Around 20 % of the area is cultivated lands, recent fill, and nearly 30 % of the area is covered by wetlands, water bodies and vegetation. Areas filled with earth are generally used for infrastructure. From the perspective of planning with solar PV-based power for Dhaka and the city's existing land cover and land use, it can clearly be seen that ground-mounted PV installations would not be feasible due to low availability of open land. No large areas of land are available for the large-scale PV plants within the urban areas of Dhaka megacity. Even the small existing patch of open space within the city left may not receive sufficient solar radiation. The peripheral areas of the cultivated or fallow spaces towards the north and northeastern parts of the DMA may be the only option to plan for SPV plants. Therefore, lands required for the large-scale (e.g. megawatt size) PV plant for either a newly built housing society or small town or shopping complex could possibly be developed in the northern parts of Dhaka megacity.

Available Roof Area

As a part of the analysis of determining factors, identification and calculation of well-illuminated rooftops in the megacity of Dhaka through object-based image analysis (OBIA) from high-resolution satellite (e.g. Quickbird) data of Dhaka were carried out (Kabir et al. 2010). A Quickbird scene of Dhaka from 2006 shows considerable heterogeneity with buildings of various characteristics, irregular roads, vegetation, water bodies, open spaces, etc. (Fig. 11.1). In order to determine the applicability of solar PV systems for a city, it is necessary to calculate the available roof area (Izquierdo et al. 2008). It is evident that not all rooftops are appropriate for PV applications; some rooftops receive less sunlight due to shading by buildings and vegetation cover. Due to the city's immense heterogeneity (Fig. 11.2), the calculation of well-illuminated roof area is a very complex task. In this study, the Quickbird image was used for this task. Although the image covers an area of 431 km^2, only the area occupied by Dhaka City Corporation (DCC) has been considered for illuminated rooftop identification and calculation (Table 11.1) (Fig. 11.1). In order to reduce complexity and error, the areas with the highest

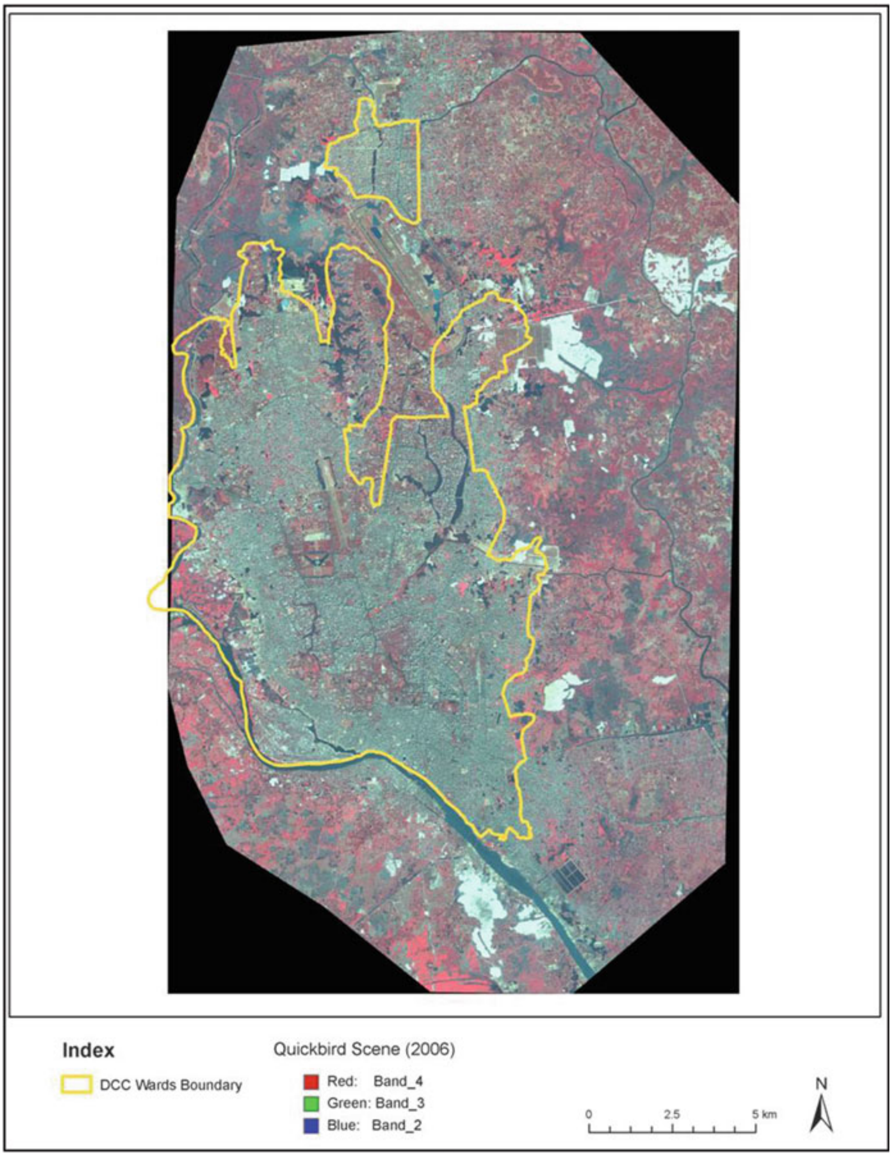

Fig. 11.1 Well-illuminated roof areas (Adapted from Kabir et al. 2010)

building density (DCC area) have been separated from the rest of the Quickbird image based mainly on field experience and visual observation. The other parts of the Quickbird image mostly contain water bodies, agricultural land, vegetation, roads and low-density buildings. It can be considered that in a very heterogeneous city like Dhaka, the calculation of well-illuminated rooftops for PV application

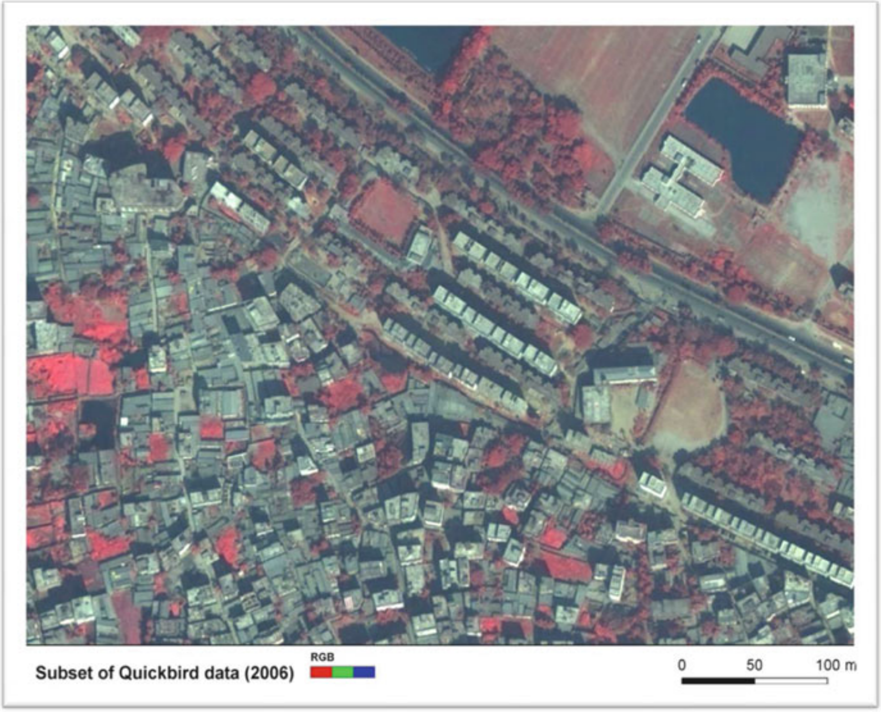

Fig. 11.2 A Zoomed-in well-illuminated roof areas in central Dhaka

Table 11.1 Calculation of well-illuminated roof area from the Quickbird image of 2006

Various objects classified	Area calculated (km^2)	% of total
Bright rooftops	10.554	7.86
Informal settlements	9.646	7.18
Vegetation	53.364	39.74
Water bodies	9.583	7.14
Others (roads, open land, shadow, etc.)	51.135	28.98
Total	134.282	100.0

Adapted from Kabir et al. (2010)

within the DCC areas would substantially contribute as very useful input data. However, from the calculation of bright rooftops within the DCC area, it has been found that the city offers 10.554 km^2 bright roof areas (Kabir et al. 2010). This figure can be considered as a conservative estimate for the entire megacity. The application of solar PV systems on these bright rooftops with 75 Wp solar panels can generate nearly 1,000 MW of electricity preferably through grid-connected PV systems (Kabir and Endlicher 2010). The potential electricity generation can be substantially high (>1,000 MW) with the installation of solar modules with high

Table 11.2 Solar PV-based power generation potential

Bright rooftop (km^2)	Bright rooftop (m^2)	GHI of Dhaka ($kWh/m^2/day$)	Module efficiency (assumed)	Module capacity (Watt)	Area needed/ module (m^2)	No. of modules to be installed in given rooftops	Potential power generation (MW)
10.55	10.55×10^6	4.20	10–15 %	75 or more	$1\ m \times 0.8\ m = 0.8$	1.31925×10^7	989.44

(Adapted from Kabir et al. 2010)

capacity (i.e. 100 Wp) and efficiency, which would sufficiently meet up Dhaka City's existing power demand (Table 11.2).

Moreover, the city has remarkable extent of informal settlements, which are widely known as slums. Nearly 40 % of the population of Dhaka megacity are slum dwellers. In 2005, 4,966 slum clusters were identified in the city, contained 3.4 million people out of city's total of nearly 9.1 million (CUS et al. 2006). From this estimation, slum population rose to 5.2 million out of total 14 million in 2009. Within the DCC area, informal settlements occupy nearly 10 km^2 (Table 11.1).

Nearly 96 % of these slum communities are provided with grid electricity but with poor connection facilities. In practice, the slums receive least attention from the authorities with regard to power supply. The rooftops of these informal settlements can be effectively used for stand-alone PV applications, using solar home systems such as those that are used in the rural areas of the country. Electricity demand in informal housing is comparatively low compared to the high- and middle-class residential buildings, and solar home systems can effectively generate enough electric power for these settlements. CUS et al. (2006) also reported that each slum cluster has ten households with at least 25 persons. If solar home systems are installed in each slum cluster commensurate with the demand, between 3 and 5 MW of electricity (600–1,000 W in each slum cluster) can be generated through the application of stand-alone PV systems. This should be adequate to meet the power needs of these communities.

11.5.1 Economic and Sociopolitical Factors

The economy and energy supply of a country are closely linked. If any of these two sectors is weak, then the other will automatically be affected (Ahmad et al. 2005). Strong economic support can ensure a society that is self-dependent in energy and enhances social development through efficient use of energy in every sector. On the other hand, energy sufficiency can help accelerate the country's economic growth. Consideration of the economic situation along with social, political and technological factors is vital for the planning and successful implementation of SPV systems. Electricity generation from solar PV is still an expensive option because the devices themselves are relatively costly. This is one of the major reasons for lower penetration of PV modules in the energy market. The slow development of PV-based power generation in the megacity of Dhaka can be blamed on the country's weak national economy. Economic factors at work include capital investment in the renewable energy sectors, local technology support and trained manpower to maintain the systems.

Financial Arrangements

Solar PV systems have always been capital intensive, but the price of PV components all over the world has been decreasing as the volume of production increases (Muneer 2004). However, it has been reported that in spite of its widespread experience with solar PV applications and their high efficiencies and reliability, the system components still appear to be expensive in developed countries such as in Germany (Erge et al. 2001). In a country like Bangladesh where at least 40 % of the population is living below the poverty line (even worse in the rural areas), it is still unfeasible among the villagers having access to solar home systems. GS has been successful in solar home system installation through its microcredit programme in the rural areas. The initial investment for solar PV installations seems high due to the price of modules, but the operation and maintenance costs are generally low as there are no moving parts in the system (Islam and Islam 2005). However, even the very low amount of payment for solar home systems appears to be impossible to many of the villagers, and this slows down penetration of the technology. The situation with solar PV system installations in Dhaka City is different in the sense that it would be highly cost intensive. Compared to the rural electricity demand, the urban demand would be substantially different, and the city dwellers are likely to be capable of paying for the expenses of the PV-generated electricity.

Local Technology Support

In order to speed up and sustain the installation of SPV systems, support from local technology providers is immensely important. It is always expensive to depend only on the foreign technologic suppliers. In Bangladesh, there are only a few private entrepreneurs involved in the promotion of solar PV system, such as Rahimafrooz which is a private company producing batteries for solar PVs. For the large-scale success of PV technology, devices should be locally available as much as possible. Even in a country where enormous potential exists, it is impossible to achieve satisfactory progress with only a few manufacturers. Along with manufacturing support, local technicians have also to install and maintain the systems. This is well understood by Grameen Shakti that has already developed a workforce of more than 2,500 skilled technicians all over the country with an especial focus on the training of female technicians. In the rural parts of the country, people are relatively conservative in allowing outsiders into their communities and homes, and in this case, female technicians are also effective in providing SPV-related training to the rural women.

Social Acceptance and People's Willingness to Pay

The assessment of social acceptability of a new technology like PV is very important in the sense that the technology has to be sustainable in the country. In the urban areas, it is possible to conduct research into people's attitudes towards adoption of PV systems. Based on the experiences of increasing numbers of solar home systems in the rural areas, it appears that people have widely accepted this technology for electricity supply, and that they are willing to pay for quality power supply. A study was carried out by Bangladesh Centre for Advanced Studies (BCAS) on 'stakeholders' opinion survey on the power sector of Bangladesh and consumers' willingness to pay (WTP) for electricity supply' (BCAS 2003), which identified several technical, financial, management and governance issues. Some of the key issues are frequent load shedding and interruption in power supply; poor power quality; high system loss due to poor technical standards; unscheduled shutdown of power supply; imbalance among generation, transmission and distribution; inadequate load management for efficient power supply; damage of devices due to voltage fluctuations; etc. Given the state of electricity supply and associated issues, the consumers are reluctant to regularly pay the bills. If the consumers are provided with continuous and good quality of power supply, they have much greater willingness to pay. To be practical with the expectation of consumer's quality and uninterrupted power supply, the existing conventional fuel-based power cannot meet their demand. However, extensive installation of solar PV systems both in the urban and rural areas can ensure quality power supply, and people will be willing to pay for the electricity. People's willingness to pay for solar electricity has also been identified by another researcher (Khan et al. 2005). That study was conducted for market assessment of the solar home systems in three subdistricts of Bangladesh that are part of the territory of the Rural Electrification Board (REB). It is found that more than two-thirds of the respondents (80.5 %) expressed their interest in obtaining some kind of solar home system. Higher-income groups showed their willingness to pay for relatively large solar home systems, whilst small-income group intended to pay for small home systems. Moreover, promotion and motivational activities through demonstration and exhibition will need to be continuously carried out for both the city and rural people to be more acquainted with new technology and to improve their willingness to pay for it.

Political Commitment and Good Governance

Political commitment is essential to a project such as the introduction of widespread SPV generation. In most cases, developing nations such as Bangladesh suffer from political conflicts over power structures and from corrupt governance. Shifting the country from a conventional energy base to new and clean energy systems requires national-level decision making, policy formulation and effective policy implementation. In order to adopt, promote and enhance renewable energy technologies (e.g.

solar PV systems) in the country, the government has to play the pivotal role and needs to be the main patron. To do this, massive countrywide PV programmes including research, development and dissemination will have to be conducted with government support. The European Renewable Energy Council (EREC) has set up a binding target for the EU as a whole and each member state, to achieve at least 20 % energy consumption from renewable sources by 2020 (Lins 2009). This is a political target which mainly encourages each member state to work towards this attainment of the goal. This can be a shining example to other developing countries that can also look forward with an aim to reach a certain target in a particular time span. In Bangladesh, the recently devised renewable energy policy is a good reflection of the government's willingness to enhance renewable energy technologies. Moreover, the rapid increase of country's electricity demand and the declining trend of indigenous gas (major ingredient of electricity generation) have also required the government to promptly decide on the massive installations of solar PV systems. In this connection, it has recently been decided that all future multistorey buildings have to have self-supplemented electricity with solar systems. Therefore, the building owners have to plan with sufficient power generation capacity with PV modules before getting the building design approved. It is important to monitor the extent to which this obligation is in fact implemented.

11.5.2 Environmental Considerations

Environmental concerns are of very practical and pragmatic consideration when considering the installation of renewable energy technologies. Given the limited reserve of conventional fuels and tremendous increase of GHG emission due to over-exploitation of fossil fuels, countries around the globe have predicted the impending dangers of inadequate power supply and climate change. On the other hand, the capital city of a developing country like Bangladesh has neither a remarkable amount of industrial development nor a sufficient power supply. The country is also not a big contributor to global greenhouse emission, but the imminent consequences of climate change in the country are likely to be severe due to sea-level rise and other climatic disturbances. Compared to industrialised countries, Bangladesh's per capita CO_2 emission (0.30 metric tonnes) is nominal, when compared to the per capita CO_2 emissions in Germany, Japan and USA which in 2004 were 9.79 tonnes, 9.84 tonnes and 20.4 tonnes, respectively (CDIAC/UN 2009). For two reasons, Bangladesh continues to reduce CO_2 emission, although it is one of the lowest CO_2 emitters on Earth. In one hand, it is an obligation for the country to participate in the efforts of global GHG emission reduction as a signatory of the Kyoto Protocol and United Nations Framework Convention on Climate Change (UNFCCC), and it is an opportunity, on the other hand, to earn money from developed countries by selling the quota of CO_2. Bangladesh has enormous potential in solar energy, and therefore, the application of small- and large-scale PV systems can help reduce its current share of GHG emission. The demand on a typical solar home system (which is normally installed in the rural areas) consists of 4 fluorescent bulbs of 7 W each, 1 black-and-white TV of 15 W and a radio of 5 W. One family using this small system can save yearly 290 l of kerosene by using solar lighting technology and can prevent the emission of 0.76 tonne CO_2 per year (SWERA/RERC 2007).

11.6 Conclusions and Recommendations

In view of the phenomenal growth of population and steady increase of electricity demand in the megacity of Dhaka, the application of PV systems (grid connected or stand-alone on bright rooftops) is essential to supplement to the increasing demand. Among the influential factors, the geophysical characteristics (geographical location, global horizontal irradiance, sunshine duration, available bright rooftops, etc.) have been found to be fully supportive to large-scale PV applications in Dhaka City, whilst sociopolitical and economic factors will not be detrimental. The city offers more than 10 km^2 of well-illuminated rooftops, by the use of which half of the city's electricity demand can be met. The development of solar home systems in the rural areas so far is considered as indicating the people's acceptance of PV technologies. The economic status of the consumers is one of the main factors determining market development of PV technologies, and given the tremendous existing power deficiency, consumers are willing to pay for PV-generated power. However, the government has a leading role to play in the case of initial investment, and there is a scope to manage big funds internationally (e.g. through carbon trading). Moreover, the currently devised renewable energy policy that targets in implementing solar PV application should immediately be in force. From the perspective of climate protection, the application of solar PV systems would be very effective as the country is a signatory to both the Kyoto Protocol and UNFCCC.

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