25. ECONOMIC ASSESSMENT OF GRID-CONNECTED PHOTOVOLTAIC SYSTEM IN BANGLADESH AND CREATION OF A VISION UP TO 2020

○Najmus SAYADAT* and Koji SHIMADA *

ABSTRACT: Bangladesh, a small developing country in South Asia, has been in energy crisis for long time that reduces country's economic growth potential. Bangladesh can actively consider a distributed power generation system alongside of its central and conventional supply system of electric power. This paper explores electricity demand and partial fulfillment of that demand through grid-connected PV system. It was found that if Bangladesh was to generate 5% of its total electricity demand by solar energy by 2020, it could be achieved by exploiting only 13% of her total technical potential. Life cycle cost analysis shows the cost of energy from grid-connected PV system is 25.5 US cents/KWh, which is much higher than the cost of electricity generated from combined cycle gas turbine. Considering the externality benefit of solar PV systems, the government should offer 30-40% of total installation cost as subsidy. This subsidy requires the government to allocate 1-1.5% of total government budget from 2010 to 2020.

KEWWORDS: grid-connected PV system, life cycle cost analysis, externality

1. INTRODUCTION

Bangladesh is an energy deficient country. Only 35% people have access to electricity and per capita electricity generation is only 155 KWh, which is among the lowest in the world (Power Cell, MEMR). Besides, regular phenomenon of power shortage, instant cut and planned cut (load shedding) incur economic loss, reduce investment potential and decrease possibility of accessing power by the rural people. Due to power shortage/cut, country's yearly loss is estimated as 1billion US$ (EIA Country Analysis Brief, August 2005). In 2004, 89% of net generation of electricity was by natural gas (PDB Annual Report, 2003-2004). Country's natural gas balance reserve as of June 2004 is 15 Trillion Cubic Feet (TCF) (Bangladesh Economic Review, 2004). At current production rate of 8%, this reserve will last up to 2016 if there is no increase in recoverable gas reserve. As a result, Bangladesh will face a clear energy shortfall and a crisis in electricity generation through conventional system within 2020 and onwards.

This paper focuses on economic assessment of grid-connected photovoltaic (PV) system for urban areas in Bangladesh and defines the period from 2010 to 2020 as a transition for initializing grid-connected system. Bangladesh is located in a very favorable place between 20.34^0N and 26.38^0N latitude and receives solar radiation of 1840 to 1972 KWh/m^2/year (Hussain & Huda, 1996). A limited scale of stand alone solar PV system has been introduced in remote rural areas, where there is no plan/way of transmitting energy through conventional grid system. Up to May 2005, total 2.872 MWp of solar PV system has been installed in all over Bangladesh and around 30 organizations are involved with this system. So Bangladesh is quite ready for grid-connected PV system installation in urban area. Although solar energy can not be a perfect substitute, it can be supportive to achieve country's goal of 'electricity for all by 2020'. Grid-connected PV system can also be a major supportive tool for achieving target of producing 10% of total electricity demand by renewable energy by 2020, enacted in Bangladesh Energy Policy 2004. However, high upfront cost of PV installation is considered as one of the major barriers that also hinders proper policy development in developing country. But if we fail to formulate long-term sustainability goals considering the cost and benefit, we will be losers and faced with long term penalties (Jacson and Oliver, 2000). We need to create a challenging vision and set strategies for achieving goals.

2. METHODS AND DATA

Electricity demand was forecasted using a long-run equilibrium relationship between per capita GDP (PGDP) and per capita electricity consumption (PCEC). The long-run relationship was identified and established

* Graduate School of Economics, Ritsumeikan University, 1-1-1 Noji Higashi, Kusatsu, Shiga, JAPAN

by Augmented Dickey-Fuller Unit Root Tests and by Engle-Granger cointegration test. The major aim of such demand forecasting is to compare with the supply side scenario and to assess the contribution of renewable energy to overall power supply. The long-term data used in this study was taken from World Development Indicator, 2004-2005, CD-ROM. GDP data was projected based on expected future growth target of Bangladesh government that are consistent with the Millennium Development Goal (MDG) and that are required for reducing income poverty specified in Poverty Reduction Strategy Paper (PRSP). For analyzing supply side scenario in terms of solar energy, methods applied in IEA-PVPS Task 7-4:2002 was employed to assess building integrated photovoltaic potential for urban areas in Bangladesh.

In analyzing microeconomic aspects, life-cycle cost analysis (LCCA) was used to find out cost per kilowatt hour of electricity through grid-connected PV system and it is compared with the combined cycle gas turbine. Solar radiation and weather data used in this paper were collected from locally, from NASA, and from Bangladesh Meteorological Department. Electricity data were collected from Bangladesh Power Development Board, from Dhaka Electric Supply Authority, and from Dhaka Electric Supply Company. Externality benefit of electricity generated from solar PV system was calculated based on results obtained from several economic and environmental paper published in international journals.

3. RESULTS AND DISCUSSION

3.1 Electricity consumption demand forecast

Using long-run equilibrium equation (1), aggregate electricity demand was forecasted, which is 75.35 TWh in 2020 (Table-1, Fig-1). The forecasted result is comparable with the projection of National Energy Policy (NEP) in 1996. The NEP projected consumption demand for 2020 is 61.98 TWh for low scenario and 92.40 TWh for reference scenario. On the other hand, Bangladesh Power System Development Plan projected required generation of 76.54 TWh in 2020. Bangladesh Power system Development Plan's generation forecast may create demand supply disequilibrium in 2020 if we consider the transmission and distribution loss.

Long-run equilibrium relationship among variables

$$PCEC = \underset{(-16.06501)^{*}}{-119.0306} + \underset{(22.05823)^{*}}{0.589442}\, PGDP \quad\ldots\ldots\ldots\ldots(1)$$

Where, $R^2 = 0.941924$, Adjusted $R^2 = 0.939988$ DW = 0.795510, F = 486.5654

Sample range: 1971-2002
t-statistics are included into parenthesis( )
* indicate significance at 1% level

Table-1: Projected electricity demand by 2020

Year	2001	2010	2020
Electricity demand, TWh	12.483*	29.206	75.356
Forecast error statistics			
Root Mean Square Error = 6.64	Mean Absolute Percent Error =18.75		
Mean Absolute Error = 4.64	Theil inequality coefficient = 0.066		

* Actual consumption in the year 2001

A sector wise electricity demand is also forecasted based on the consumption ratio in 2003-2004 assuming that this consumption pattern will continue up to 2020 (Table-2, Fig-2).

Table-2: Sector wise electricity demand forecast, TWh

Year	Residential	Commercial	Industrial	Irrigation	Others	Total
2001	5.371	.937	5.440	0.494	0.240	12.483*
2010	12.569	2.193	12.729	1.154	0.562	29.206
2020	32.429	5.657	32.842	2.978	1.450	75.356

* Actual consumption in the year 2001

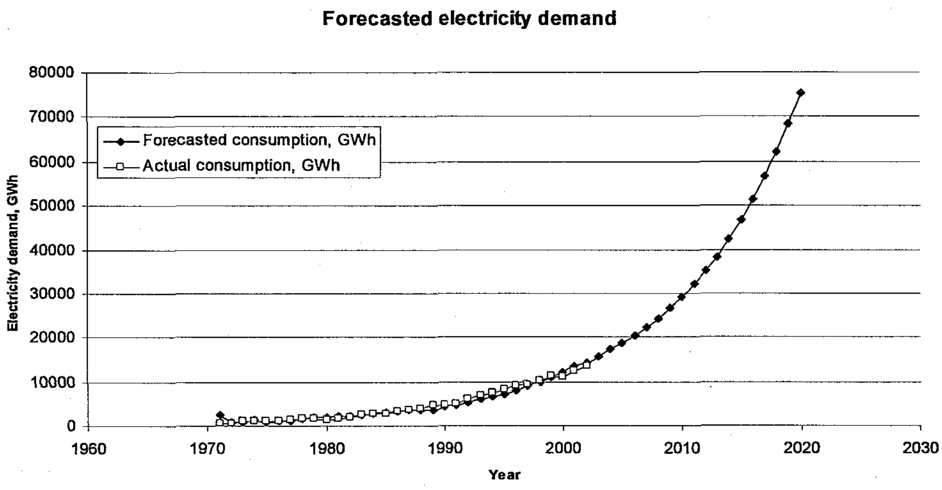

Figure-1: Forecasted electricity demand

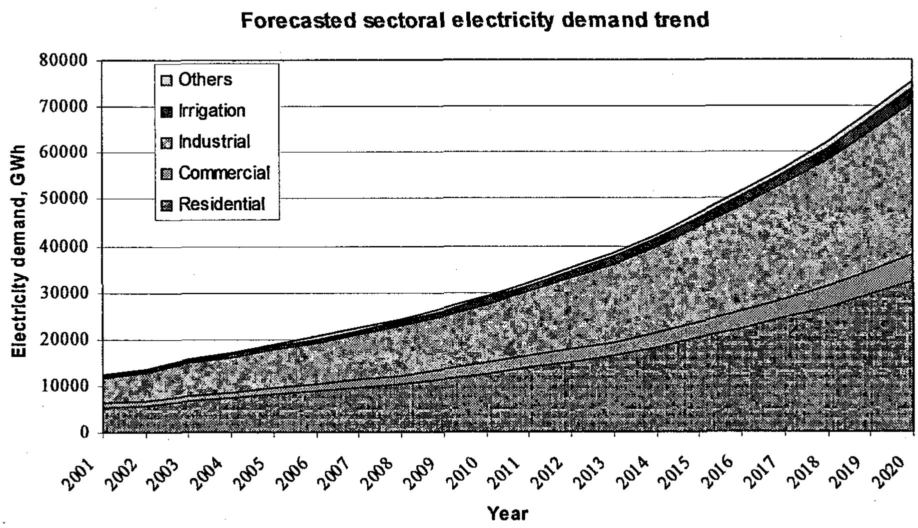

Figure-2: Sector wise forecasted electricity demand

3.2 Electricity production potential by grid-connected PV system

Daily average solar insolation in Bangladesh varies between 4 to 6 KWh/m^2. Maximum amount of insolation is available in the month of March, April and May and minimum in December-January. Though there is a little difference in monthly solar insolation at different cities of Bangladesh, solar insolation on Dhaka city is taken as standard measures (Fig-3). Sunlight is abundant throughout the year in all over Bangladesh. Even during the monsoon rainy season, solar insolation is as good as the annual average.

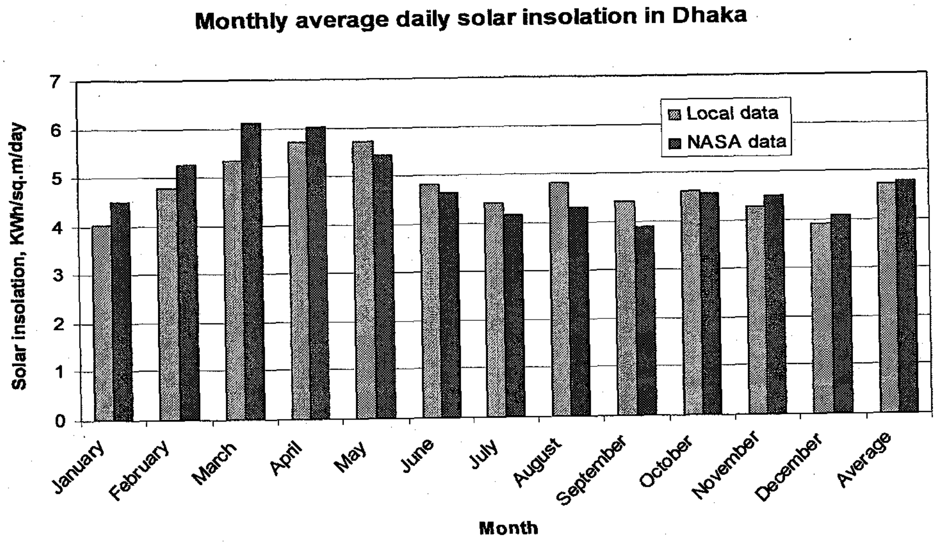

Figure-3: Monthly average daily solar insolation in Dhaka city

IEA-PVPS method for theoretical potential calculation includes the theoretical maximum use of all possible areas of building envelops i.e., roof and façade surface, as mounting structures for PV modules in urban areas. It was found that roof surfaces alone produce 80% electricity of total production potential (Table-3).

Table-3: Electricity production potential by grid-connected PV systems in Bangladesh

Year	On roofs, TWh/y	On façade, TWh/y	Total production potential, TWh/y	Electricity demand, TWh/y	Potential/demand (%)
2001	10.187	2.486	12.673	12.483	102
2010	15.289	3.730	19.019	29.206	65
2020	23.006	5.613	28.619	75.356	38

3.3 Life cycle cost analysis (LCCA)

In project evaluation, life cycle cost analysis (LCCA) is usually used in which all costs arising from owning, operating, maintaining, and ultimately disposing of remnants are taken into account. As it permits inclusion of the impact of the changing economic variables, i.e., interest rates, inflation rate, some other escalation rate and discounted future values, LCCA is used for better comparison with several cost effective alternatives. This study assessed life cycle cost of electricity generation with following equations.

$$LCC = C_{Initial\ investment} + O\&M_{pv} + R_{pv} + FC_{pv} + XC_{pv} - SV_{pv} \qquad (2)$$

Where,

LCC : Life cycle cost
$C_{Initial\ investment}$: Initial capital investment
$O\&M_{pv}$: Present value of operation and maintenance cost
R_{pv} : Present value of replacement cost
FC_{pv} : Present value of fuel cost
XC_{pv} : Present value of external cost
SV_{pv} : Present value of salvage value

Life Cycle Energy Cost:

$$LCEC = \frac{LCC}{E} \quad \text{..} (3)$$

Where, LCEC: Life cycle energy cost per KWh, E: total energy production in KWh

The life cycle energy cost of grid-connected PV system is found 17.74 taka (25.53 US cents) per KWh, which is much higher than the cost of combined cycle gas turbine, 1.142 taka (1.92 US cents) per KWh. As shown in Table-4, externality benefit for grid-connected PV system was estimated as 5.048 taka (8.48 US cents).

Table-4: Externality benefit per KWh of electricity produced by grid-connected PV system

Parameters	**Cost**	**Sources**
Total capital cost avoided	0.274	Duke, R., Williams R, and Payne, A. 2005
O&M cost avoided	0.095	
Fuel cost avoided	0.772	
Externality cost avoided	1.447	Roth, I. F. and Ambs, L. L., 2004, Jose L. B et. al., 2006, Kordy, M.N. E., et.al., 2002
Distributed benefit	0.342	Duke, R., Williams R, and Payne, A. 2005
Transmission & Distribution loss avoided	2.118	Alam et.al., 2004
Total cost avoided, Taka/KWh	**5.048**	

3.4 DISCUSSION

A major objective of Bangladesh government's Renewable Energy Policy is to generate power utilizing renewable energy to share at least 5% of total demand by 2010 and 10% by 2020. With the line of this policy objective, production requirement by grid-connected PV system by about 5% of total electricity demand in 2020 is examined. To achieve this goal, it is necessary to produce 3.768 TWh of forecasted electricity by 2020 through grid-connected PV system, which is only 13% of total technical production potential. To achieve this target, the government needs to implement at least 1.03 million grid-connected PV systems of at least 2KWp system, starting from 2010 to 2020. For such implementation in residential and other infrastructure, the government has to offer subsidy. Considering the cost avoided per KWh of electricity the government should offer 30-40% of total installation cost as subsidy. This government expenditure is estimated as 1-1.5% of government budget of each year from 2010 to 2020. Again if sector wise demand is considered, it is found that if government take initiative of producing 5% electricity from PV system, it covers 12% of residential demand, 67% of commercial demand, 11% of industrial demand, and it can cover more than required demand in irrigation sector in 2020.

4. CONCLUSION

Bangladesh needs electricity for its sustained growth and better life. Country wide implementation of grid-connected PV system will be the one of the best complement to conventional method. So, it requires government policy initiative and budgetary allocation. In this context, we found the following points in this study:

- Bangladesh needs 75.356 TWh electricity in 2020 to meet the demand. Grid-connected PV system can provide 38% of this total electricity requirement with utilizing full technical potential. If Bangladesh wants to generate 5% electricity from solar energy, it can be generated by utilizing only 13% of technical potential.
- Cost of generating electricity in Bangladesh is around 25.5US cents/KWh, while the cost is around 1.9 US cents/KWh in advanced combined cycle gas turbine. Externality benefit from producing electricity by PV system is 8.5 US cents/KWh.
- Considering the externality benefit, the government should offer subsidy amounting 30-40% of total installation cost. The government needs to allocate 1-1.5% of its budget for this purpose.

REFERENCES:

Alam et.al. 2004. Power Sector Reform in Bangladesh: Electricity distribution system. Energy. Vol 29. 1773-1783.

Annual Report 2003-2004. Bangladesh Power Development Board.

Bangladesh Economic Review 2004. Ministry of Finance. Government of the People's Republic of Bangladesh.

Bangladesh Renewable Energy Newsletter. Vol 5. No.1 &2. 2004.

Duke, R., Williams, R. and Payne, A. 2005. Accelerating residential PV expansion: demand analysis for competitive electricity markets. Energy Policy. Vol 33. 1912-1929.

EIA country analysis brief. http://www.eia.doe.gov/emeu/cabs/bangla.html updated in August 2005.

Hussain, M. and Huda, A.U. 1996. "Optimization of the tilt angle for inclined collectors at Dhaka", *Proceedings of World Renewable Energy Congress.* 1824-1827, Congress held at Denver, CO, 15-21 June.

Jacson, T. and Oliver, M. 2000. The Viability of solar photovoltaics. Energy Policy. Vol 28, Issue 14. 983-988.

Roth, I. F. and Ambs L. L. 2004, Incorporating externalities into a full cost approach to electric power generation life-cycle costing. Energy. Vol 29 . 2125-2144.

Jose, L. B. and Rodolfo D.L. 2006. Economical and environmental analysis of grid connected photovoltaic systems in Spain. Renewable Energy. Vol 31. 1107-1128.

Lotte, S. 2000. Comparison of methodologies for externality assessment. Energy Policy. Vol 28. 1127-1136.

Kordy, M.N.E. et.al. 2002. Economical evaluation of electricity generation considering externalities. Renewable Energy. Vol 25. 317-328.

Power Cell webpage. Ministry of Power, Energy and Mineral Resources. Government of the People's Republic of Bangladesh. http://www.powercell.gov.bd/index.php?page_id=225.

Sundqvist, T. 2004. What causes disparity of electricity externality estimates? Energy Policy. Vol 32. 1753-1766.