Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 52 (2014) 410 – 420
Energy Procedia

2013 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Electricity generation expansion planning with environmental impact abatement: Case study of Bangladesh

Md. Ahsan Habib[a], Supachart Chungpaibulpatana[a*], a*

[a]School of Manufacturing Systems and Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University, Pathumthani-12121, Thailand

Abstract

This paper analyzes utilization of renewable energy with domestic coal in place of import coal and oil in Bangladesh Power System from 2010-2030. Therefore, the modelling of long-term renewable and domestic coal utilization is examined in terms of expansion cost and environmental impacts. The results show that in 2030, the required electricity generation to fulfil future demand is estimated 162 TWh. Under the BAU scenario, the share of coal is 33% of total electricity generation mix. However, under the null coal import scenario the installed power plant from renewable sources increase to be 47 GW and coal utilization decreases to be 35 GW or 16% of total electricity generation share. The null coal import scenario reduces coal utilization by up to 52%. Under the limited coal and oil import scenarios, the share of coal becomes 60 GW or 27% of total electricity generation mix. In the economic and environmental perspective, more renewable based power plants need to be developed in order to reduce import coal and oil utilization in power generation. In the end of planning horizon, the BAU scenario emits as much as 96 million tons of CO_2 equivalents, while the null coals import scenario successes to reduce emissions by 39 million tons from the BAU scenario's emissions.

Keywords: Bangladesh; Electricity crisis; Renewable energy; Environmental impacts; Emissions reduction.

1. Introduction

The electricity generation expansion planning involves the selection of generation technology options to be added to an existing system, when and where they should be constructed to meet the growing energy demand over a planning horizon time. The generation expansion planning problem is well studied, with many of the studies focus on finding the least cost expansion plan. However, there are many conflicting

* Corresponding author. Tel.: +6-681-890-7309
E-mail address: supachar@siit.tu.ac.th

Selection and peer-review under responsibility of the Organizing Committee of 2013 AEDCEE
doi:10.1016/j.egypro.2014.07.093

objectives in the generation expansion planning such as environmental impact, reliability, imported fuel, safety and so on [1]. Moreover, there are uncertainties associated with the input data such as demand forecasts, availability of fuel, investment, input fuel prices, transmission network and others.

In the worldwide total energy demand, the share of fossil energy is around 80%, while the remaining 20% are supplied by nuclear and renewable energy [2, 3]. In 2005, a total of 26.6 billion tons of CO_2 emissions were generated world-wide of which more than 41% was from power generation based on fossil fuels [3, 4]. The CO_2 emissions from power generation are projected to increase 46% by 2030 [3, 4]. This particular greenhouse gas (GHG) is a culprit for an array of undesired and soon irreversible chain of events worldwide. In March 1994, the United Nations Framework Convention on Climate Change entered into force. It encouraged governments to gather and share information on GHG emissions and practices that could lessen these GHG emissions [5]. Soon after, in 1997, the Kyoto Protocol was adopted and ratified by most of the leading industrial countries. Instead of encouraging governments, the latest Kyoto Protocol bound ratified governments and set emission target that average to six percent below that of 1990 for a span of five years period from 2008-2012 [5]. Bangladesh is considered extremely vulnerable to the impacts of climate change. While there has been no clear road map from Bangladesh government to develop an electricity generation expansion planning where demand is satisfied at the least cost with considering environmental impact abatement.

There are many mechanisms for reducing CO_2 emissions from the power sector and one of the most practical mechanisms is the switching from high to less or non-carbon intensive sources of generations [6, 11]. In this study, system expansion cost and environmental effect in terms of CO_2 emission mitigation up to 2030 for Bangladesh Power System is analyzed with respect to Business as usual, Limited coal and oil import and Null coal import scenarios.

2. Power sector in Bangladesh

The rapid increase of economic and population growth has resulted in increasing electricity demand in Bangladesh. As one of the developing countries and among the world's most densely populated nations [7, 12], Bangladesh is facing acute shortage of electricity supply. Bangladesh lacks sufficient electricity generation capacity and electricity grid networks to electrify the whole nation and has never enjoyed 100% electrification. Overall, the nation's power generation units have been chronically unable to meet system demand over past decade [8, 12]. Currently, electricity generation per capita in Bangladesh is one of the lowest in the world, about 236 kWh/Capita including captive power generation [9]. Its electrification rate in 2005 was 44% (National census in 2005) and increased to 48.5% in 2010 [9]. Energy pattern in Bangladesh is mono-fuel dependent, i.e. indigenous natural gas. About 88.5% of total electricity generation is from natural gas and the remainder is entirely from oil, coal and hydropower [9]. Electricity generation from coal is only 3.75% though there are lots of potential. Share of Renewable is very negligible.

The government of Bangladesh has declared that it aims to provide electricity for all by the year 2021[10], although at present there is high unsatisfied demand for energy. Coal is expected to be the main fuel for electricity generation. According to Power System Master Plan, the government of Bangladesh has planned to generate 11,450 MW power from domestic coal and 8,400 MW from import coal within 2030 [10] ,although coal power has adverse environmental effects. The government has also focused on liquid fuel based peaking and rental power plants [10]. As a result, the share of CO_2 emissions coming from fossil fuel based power plants in the national CO_2 inventory is expected to grow.

Increasing the use of fossil fuels to meet the growing worldwide electricity demand, especially in developing countries, not only counteracts the need to prevent climate change globally but also has negative environmental effects locally [3]. In Bangladesh, the power sector alone contributes 40% to the total CO_2 emissions [3, 13]. In this case, it is necessary to develop and promote alternative energy sources that ensure energy security without increasing environmental impacts.

3. Coal potential [10]

According to the present development data, there are five coal fields in Bangladesh, all of which situated in between the Jamuna River and the Padma River in the north-western part of Bangladesh. The measured and probable coal reserves total 3.3 billion tons. According to the Draft Coal Policy (June 2007), the measured coal reserve that can be mined for the time being is estimated to be 1,168 million tons, except in Jamalgonj where coal seams are located relatively deep underground. As developments continue, probable coal reserves are likely to increase. Table 1 shows the coal reserve in Bangladesh.

Table 1. Coal reserve in Bangladesh [10]

Serial no.	Coal field name	Development year	Depth (m)	No. of coal seams	Measured coal reserve (million tons)	Measured+ probable coal reserves (million tons)
1	Barapukuria (Dinajpur)	1985 -87	118 -506	6	303	390
2	Phulbari (Dinajipur)	1997	150 -240	2	572	572
3	Khalaspir (Rangpur)	1989 -90	257 -483	8	143	685
4	Dighipara (Dinajpur)	1994 -95	328 -407	5	150	600
5	Jamalgonj (Bogra)	1962	640- 1,158	7	1053	1,053
6	Kuchma (Bogra)	1959	2,380 -2,876	5	-	-
Total						3,300

4. Renewable energy potential

Bangladesh is endowed with plentiful supply of renewable sources of energy. Out of various renewable sources solar, wind, biomass and hydro-power can be effectively used in Bangladesh.

4.1 Solar Energy

Bangladesh is situated between 20.30^0 and 26.38^0 north latitude and 88.04^0 and 92.44^0 east longitude with an area of 147,500 km^2, which is an ideal location for solar energy utilization. Annual amount of radiation varies from 1840 to 1575 kWh/m^2 which is 50-100% higher than in Europe [14]. The technical potential of grid-connected solar photovoltaic is estimated at 50,174 MW [26]. Solar radiation varies from season to season in Bangladesh. So, we might not get the same solar energy all the time. Maximum amount of radiation are available in the month of March-April and minimum in December-January [15, 16]. In Fig.1 the monthly average solar radiation pattern is shown.

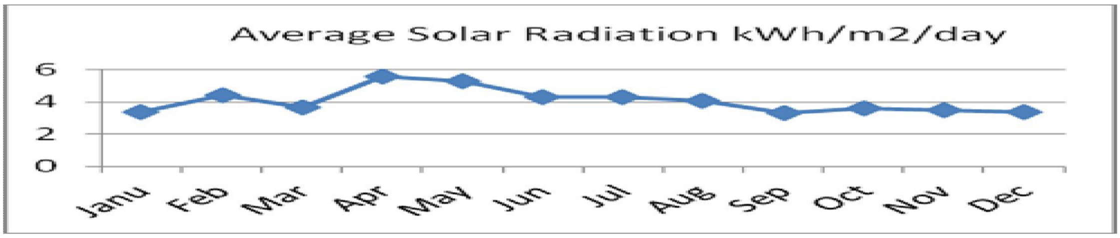

Fig 1. Monthly average solar radiation profile in Bangladesh [15-16]

4.2 Wind Energy

Assessment of the wind energy resource and the installation of wind energy conversion systems in Bangladesh have long been hindered due to lack of reliable wind speed data. There is no reported wind map of Bangladesh that could be relied upon and used for wind energy assessment [3, 17]. Several locations in the coastal belt have been assessed to evaluate the wind energy potential. The maximum average wind speed is during the month of April which is approximately 5.3 ms-1 and minimum in the month of December which is around 2.6 ms-1 in Bangladesh [16, 18]. The technical potential of wind energy is estimated at 4,614 MW [26].

4.3 Biomass

Cattle dung, agricultural residue, poultry dropping, water hyacinth, rice husk etc. used for biomass power generation are available in Bangladesh [16, 19]. The total annual recoverable rate of biomass in Bangladesh is about 126 mton per year [3]. 50 % of the rice husks are used for energy applications such as domestic cooking and steam production for rice parboiling. Therefore, 50 % of the rice husks can be used for power generation. Only 57 % of poultry droppings are viable for small-scale power generation [3, 20]. The technical potential for biomass energy is estimated as 566 MW [26].

4.4 Hydro-Power

Due to the nation's flat terrain and potentially large social and environmental impacts, further exploitation of hydropower is expected to be limited [12]. The estimated exploitable capacity for hydropower generation is 745 MW, of which around 200 MW is by small- and mini-sized hydro power plants [21]. In 2010, the total installed capacity of hydropower plants was 230 MW. It is planned that a 100 MW extension of the Karnafauli hydropower plant will be added in 2016 [10].

5. Leap methodology

The Long-range Energy Alternatives Planning (LEAP) model used in this study is a scenario-based energy environment modelling tool which was developed by the Stockholm Environment Institute. The main concept of LEAP is the end-use driven scenario based analysis. Its scenarios are based on comprehensive accounting of how energy is consumed, converted, and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology and so on [22].

For environmental assessment, LEAP can provide the results of pollution emission factors from each stage of fuel processing in power generation, including the cost of generating electricity and greenhouse gas emissions, extraction process, distribution, and the end-use activities [23]. In some researchers, LEAP model was used to simulate emission inventories and external costs of fossil electricity generation along with different future energy consumption patterns and pollutants abatement policies under user-defined assumptions [24].

6. Key assumptions

In order to develop future electricity generation expansion plan the current situation must be understood and accurately input in LEAP. However, data of this nature takes time to compile and requires making assumptions when data is not available. A large portion of the data that makes up the platform is taken from Bangladesh Power System Master Plan-2010 [10] and Bangladesh Power Development Board Annual Report 2009-2010 [9]. In 2010, Bangladesh's population was 160 million with the national gross domestic product (GDP) of 79 billion US dollars [10]. Based on the world development indicators, Bangladesh population will increase with an average growth rate of 1.39% per year, with the annual GDP growth rate of 7% up to 2030. We assumed that the population and the GDP growth rate are still kept stable and continuing to the end of 2030. An average household has around 5 members, and the total number of households in the country is 32 million.

7. Scenario analysis

7.1 Business as Usual (BAU) Scenario

In this study, the BAU scenario starts from 2010 as the base year. The data on existing, committed and candidate power plants used in this study are based on Bangladesh Power Development Board Annual Report 2009-2010 [9] and Bangladesh Power System Master Plan-2010 [10].
In 2010, the total dependable generation capacity was 5,132 MW [10]. All existing, committed and candidate power plants are dispatched based on their ascending running cost.

Table 2 shows the committed import coal based steam power plants in Bangladesh from 2016 to 2030. The reasons for import coal for power plants can be explained by two major factors (1) Domestic coal development is facing trouble. Debate is continuing about mining method whether it will be open cut or underground mining. (2) The switch from gas to coal based power plants leads to a strong increase in coal consumption. This coal consumption rate is higher than the domestic availability.

Table 2. Committed import coal based power plants [10]

Name of Power Plant	Type	Capacity (MW)	Commissioning Year
Khulna South	Coal Steam	1,200	2016
Chittagong	Coal Steam	1,800	2017
Meghnagatt	Coal Steam	600	2018
Matarbari	Coal Steam	600	2023
Matarbari	Coal Steam	600	2026
Meghnagatt	Coal Steam	600	2026
Mawa	Coal Steam	1,200	2027
Matarbari	Coal Steam	600	2029
Zajira	Coal Steam	600	2029
Matarbari	Coal Steam	600	2030
Total		8,400	

Bangladesh government has planned to import the hydro electric power from Bhutan, Nepal and Myanmar as there is large-scale hydro-power potential to these neighbouring countries. Table 3 shows the proposed hydro electricity import from neighbouring countries to Bangladesh from 2018-2030.

Table 3. Proposed hydro electricity import from neighbouring countries [10]

Station Name	Type	Grid	Capacity (MW)	Commissioning Year
Myanmar to Bangladesh	Hydro	Inter connection	500	2018
Nepal to Bangladesh	Hydro	Inter connection	500	2023
Bhutan to Bangladesh	Hydro	Inter connection	500	2023
Total			1,500	

Bangladesh government has also planned to set up four nuclear power plants to mitigate the future electricity demand [10]. Two nuclear power plants each of 1,000 MW capacities is going to be installed by the help of Russia. The plants will implement new safety features following the nuclear accident in Fukushima in Japan. The first and second unit will be commissioned by 2017 and 2018 respectively. Another two units each of 1,000 capacities will also be commissioned in 2024 and 2025.

Bangladesh is going to be established cross border trading (1,750 MW electricity) with the neighbouring countries [10]. Cross border trading is meaningful not only for import power to supplement Bangladesh's power supply, but also for export power to the neighbouring countries when sufficient power in Bangladesh due to seasonal and/or time difference. This could improve the overall system efficiency; ensure the reserve margin and reliability by effective plant utilization.

7.2 Limited Coal and Oil Import Scenario

In the limited coal and oil import scenario, renewable energy resources (i.e. Solar, Wind, Hydro, and Biomass) will be used optimally to reduce import coal and import oil utilization in the power sector as well as to fulfil the electricity demand with clean power generation. In addition to renewable energy resources, other types of power plants are also used as additional capacity; namely, 1) combined cycle, 2) gas turbine, 3) coal steam, 4) liquid fuel-based and 5) Nuclear power plants.

7.3 Null Coal Import Scenario

The null coal import scenario assumes a particular policy development in the import of fossil fuels. The intension is to use more renewable energy resources and reduce the import of coal for electricity generation. This constraint specifies that there is no imported coal available for power generation.

8. Results and discussions

8.1 Business as usual (BAU) scenario

Fig. 2 shows the electricity demand in the BAU scenario. At the end of the period the demand has increased nearly five times, compared to the base year. In 2010, the initial electricity demand was 33,922 GWh and with this forecast the demand in 2030 grew to 162,490 GWh.

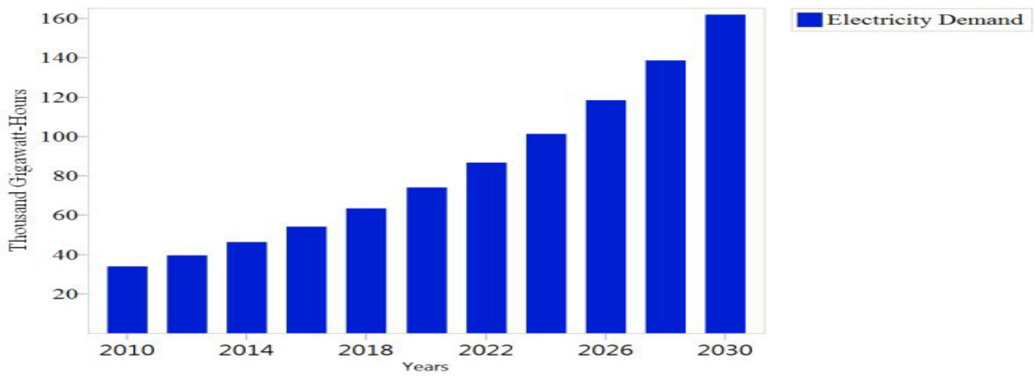

Fig 2. Electricity demand

In the base scenario, the total generation capacity is expected to increase from 5.1 GW in 2010 to 36.3 GW in 2030. At the same time, the generation structure changes significantly. The share of gas-based power plants reduces from 88.5% (4.3 GW) in 2010 to 23% (8.4 GW) in 2030 in total capacity, whereas the increase in the share of coal-based power plants 3.75% (0.2 GW) in 2010 to 54% (19.6 GW) in 2030 is extremely high.

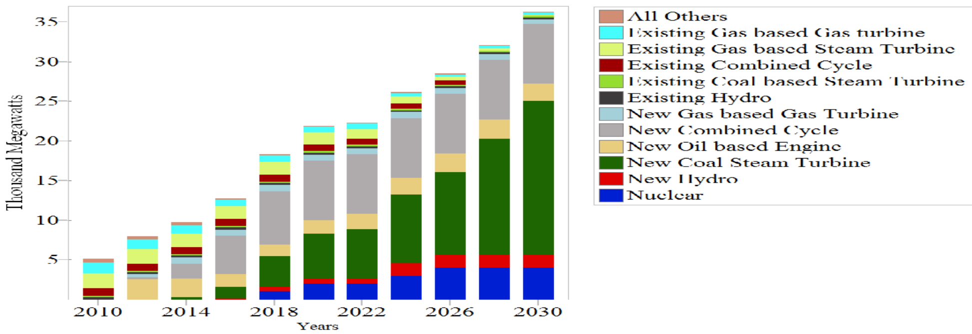

Fig 3. Existing and committed generation capacity

Fig. 3 shows the existing and committed generation capacity up to 2030 for the base scenario. From figure 3 it is clear that the country would need to import coal from 2016 onwards to meet the required demand. In case of oil the share of import oil based power plants also increases from 0.47 GW in 2010 to 2.2 GW in 2030. As a result this deficiency would have adverse impacts on the country's balance of payment and the availability of foreign currency resources.

8.2 Limited coal and oil import scenario

Fig. 4 shows the limited coal and oil import scenario electricity generation capacity up to 2030. In the limited coal and oil import scenario, power generation from coal based power plants decreases by 1.2 GW, 1.7 GW and 4.9 GW in 2022, 2025 and 2030 respectively and power generation from renewable energy resources increases by 0.5 GW, 1.4 GW and 5.4 GW in 2020, 2025 and 2030 respectively compared to BAU scenario. The share of import oil based power plants reduces by 0.4 GW, 0.8 GW and 0.7 GW in 2020, 2025 and 2030 respectively compared to BAU scenario.

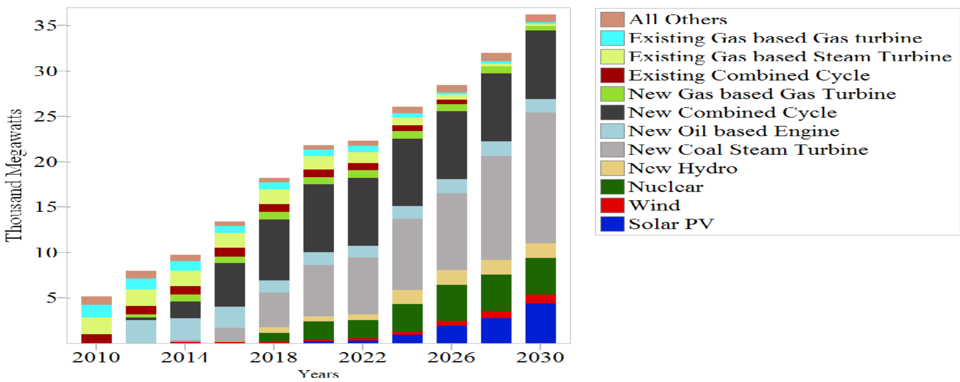

Fig 4. Limited coal and oil import scenario

8.3 Null coal import scenario

In this scenario, renewable energy resources (i.e. Solar, Wind, Hydro, and Biomass) will be used more so that there is no imported coal available for power generation. Fig. 5 shows the null coal import scenario electricity generation capacity up to 2030.

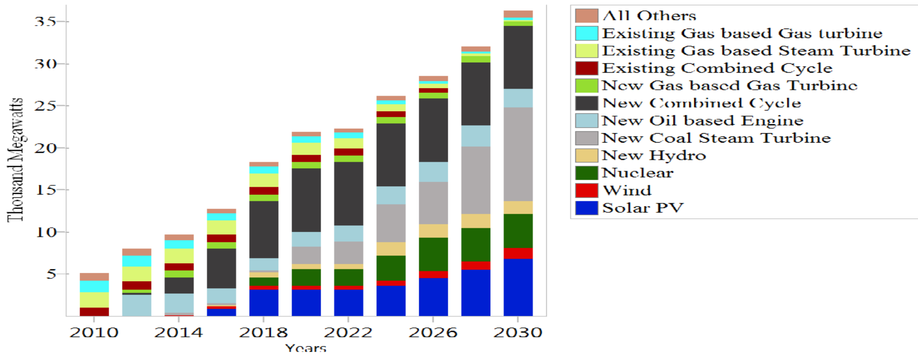

Fig 5. Null coal import scenario

In the null coal import scenario, total renewable energy generation capacities increase to about 9.7 GW by 2030. The share of coal based power plants reduces by 3.7 GW, 5.1 GW and 8.3 GW in 2020, 2025 and 2030 respectively compared to BAU scenario. Under this constraint, oil based power plant are also selected due to increase in demand.

8.4 Environmental Emissions

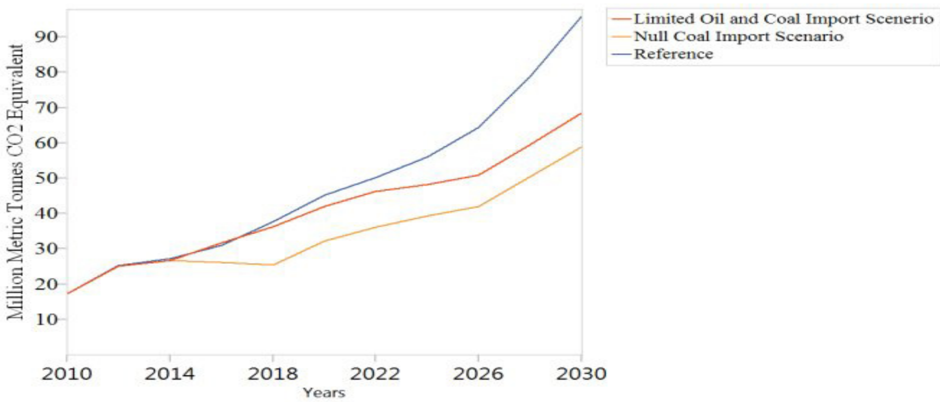

Fig 6. Environmental emissions of all scenarios

The power generation is always associated with the greenhouse gases. The energy generation releases emissions to the atmosphere, and then it causes the global warming. The global warming potentials are always expressed relatively to level of CO_2. CO_2 emission reduction directly affects the shift of technologies from high carbon content fossil-based to low carbon content fossil-based and clean renewable energy-based technologies. Fig. 6 represents the environmental emissions of BAU (Reference), limited coal and oil import and null coal import scenario.

From fig. 6 it can be seen that from year 2014 the limited oil and coal import scenario and null coal import scenario start to get lower than the emissions from BAU scenario. In the end of planning horizon, the BAU scenario emits as much as 96 million tons of CO_2 equivalents, while the null coal imports scenario successes to reduce emissions by 39 million tons from the BAU scenario's emissions.

8.5 Economic perspective

Determining costs for electricity generation expansion plan can be very complicated and tedious to properly develop. However, for our analysis between the BAU scenario and the alternative scenarios, introduced in the following section, the costs can be simplified to a few key areas. The itemized costs for the electricity generation facilities are the capital costs of the added capacity and the fixed and variable O&M costs for all the power plants. Here it is mentioned that costs may be vary based on manufacturing country, technology, time, user country and so on. Table 4 presents components of cost in all scenarios.

Table 4. Components of cost in all scenarios

Type of Power Plant	Capital Cost (10^3 US$/MW)	Fixed O&M Cost (US$/MWh-Year)	Variable O&M Cost (US$/MWh)	Reference
Existing Coal Steam	-	71,400	5.2	BPDB 2010 [9]
Existing Oil Combustion Turbine	-	31,200	3	
Existing Gas Turbine	-	15,600	3.25	BPDB 2010 [9]; PSMP 2010 [10]
Existing Combined cycle	-	19,560	1.69	
New Coal Steam	1,440	53,280	3.04	PSMP 2010 [10]
New Gas Turbine	550	15,600	3.25	
New Combined Cycle	860	8,400	1.34	
New Oil Fired Engine	1,130	30,120	1.72	
Nuclear	2,400	-	-	
Solar PV	2,200	38,562	-	A H Mondol 2010 [3]; IRENA 2012 [25]
Wind	1,800	18,888	-	
Biomass	1,880	29,400	-	
Hydro	2,000	31,200	-	

From table 4 in case of capital cost, the nuclear plant has the highest cost, which is US$ 2.4 million per MW. Meanwhile, capital cost of the solar PV is about US$ 2.2 million per MW. In case of fixed O&M cost, the coal based steam plant is the most expensive while the cheapest is the gas based new combined cycle plant. At the end of the period, the null coal import scenario is the most expensive scenario compared to the other scenarios (Table 5). The BAU scenario is the cheapest scenario since it uses more conventional fuel. Table 5 presents the total cost of each scenario.

Table 5. Total cost in all scenarios

Scenario	Total Cost (US$ billions)				
	2010	2015	2020	2025	2030
BAU	0.2	1.4	3.8	5.7	7.7
Limited oil & coal import	0.2	1.4	3.9	5.6	8.0
Null coal import	0.2	1.4	4.1	5.7	8.2

9. Conclusion

Electricity is the key to all development. For improvement of quality of living, and for overall development of the economy, demand of electricity is increasing day by day. However, power generation capacity of the country did not increase at the rate required to meet the demand during past years. Following the high electricity demand growth, Bangladesh is facing acute shortage of electricity.

The results show that the null coal import scenario (referred to here after as renewable scenario) is not going to be the lowest total system cost since renewable energy investment is more expensive compared to other energy sources. However these total system costs are much lower than those in developed countries, as the renewable-energy-based power generation is relatively much cheaper in Bangladesh [3]. This study also provides an idea of the renewable energy potential, and demonstrates to which extent renewable energy technologies can be integrated into the Bangladesh power sector. It could thus be attractive for developed countries (so-called Annex 1 countries in the UNFCCC) to invest in renewable energy technologies, specifically in solar PV, in Bangladesh to reduce their committed CO_2 emissions defined in the Kyoto Protocol through the clean development mechanism (CDM).

Acknowledgement

The authors would like to acknowledge Asian Development Bank for providing the ADB-Japan Scholarship and the first author are grateful to Ministry of Power, Energy and Mineral resources of Bangladesh and Bangladesh Power Development Board for supporting the study.

References

[1] Hatice Tekiner, David W. Coit, Frank A. Felder, Multi-period multi-objective electricity generation expansion planning problem with Monte-Carlo simulation, Electric Power Systems Research 80 (2010) 1394-1405.
[2] Rout UK, Modeling of endogenous technological learning of energy technologies-an analysis with a Global multiregional energy system model, Ph.D. Dissertation, University of Stuttgart, 2007.
[3] M. A. H. Mondal, Implications of renewable energy technologies in the Bangladesh power sector: Long term planning strategies, Ph.D. dissertation, Dept. of Ecology and Natural Resources Management, ZEF, University of Bonn, Germany, Jul. 2010.
[4] World energy outlook-2007, International Energy Agency.
[5] Tule Sirikitputtisak, Hamidreza Mirzaesmaeeli, Peter L. Douglas, Eric Croiset, Ali Elkamel, Murlidhar Gupta, A multi-period optimization model for energy planning with CO_2 emission considerations, Energy Procedia 1 (2009) 4339-4346.
[6] Hadley, S.W. Short, W., Electricity Sector Analysis in the Clean Energy Future Study. Energy Policy 29 (2001), 1285-1298.
[7] Bangladesh: country profile, The Economist Intelligence Unit (EIU), London, 2005.
[8] Bangladesh: country analysis briefs, Energy Information Administration, Washington DC, 2005.
[9] Bangladesh Power Development Board Annual Report 2009-2010.
[10] Japan International Cooperation Agency (JICA), Tokyo Electric Power Co., Ltd. Bangladesh Power System Master Plan PSMP-2010.

[11] Jerasorn Santisirisomboon, Bundit Limmeechokchai, Supachart Chungpaibulpatana, Least cost electricity generation options based on environmental impact abatement, Environmental Science & Policy 6 (2003) 533-541.
[12] Sk Noim Uddin and Ros Taplin, A Sustainable Energy Future in Bangladesh: Current Situation and Need for Effective Strategies, The 2nd Joint International Conference on "Sustainable Energy and Environment (SEE 2006)" 21-23 November 2006, Bangkok, Thailand.
[13] Shrestha RM, Anandarajah G, and Liyanage MH, Factors affecting CO2 emission from the power sector of selected countries in Asia and the Pacific, Energy Policy (2009) 37:2375-2384.
[14] Eusuf M., Solar Photovoltaic Systems in Bangladesh: Experiences and opportunities. The university press limited, Dhaka, Bangladesh, 2009, pp 75-84.
[15] Khairul Anam, Husnain-Al-Bustam, "Power Crisis & Its Solution through Renewable Energy in Bangladesh", Cyber Journals: Multidisciplinary Journals in Science & Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE), September -2011.
[16] Nahid-ur-Rahman Chowdhury, Syed Enam Reza, Tofaeel Ahamed Nitol, Abd-Al-Fattah-Ibne Mahabub, Present Scenario of Renewable Energy in Bangladesh and a Proposed Hybrid System to Minimize Power Crisis in Remote Areas, International Journal of Renewable Energy Research Vol.2, No.2, 2012.
[17] Khan MJ, Iqbal MT, and Mahboob S , A wind map of Bangladesh, Renewable Energy (2004) 29: 643-660.
[18] Mir Nahidul Ambia, Md. Kafiul Islam, Md. Asaduzzaman Shoeb, Md. Nasimul Islam Maruf, A.S.M. Mohsin, An Analysis & Design on Micro Generation of A Domestic Solar-Wind Hybrid Energy System for Rural & Remote Areas-Perspective Bangladesh, 2010.
[19] Bangladesh Gazette: Renewable Energy Policy of Bangladesh 2008, published in November 06, 2008.
[20] Zaman SAU, The potential of electricity generation from poultry waste in Bangladesh: A case study of Gazipur district, Dissertation, University of Flensburg, 2007.
[21] Wazed MA and Ahmed S, Micro hydro energy resources in Bangladesh: A review. Aust. J. Basic Appl. Sci. (2008) 2(4): 1209-1222.
[22] Stockholm Environment Institute, Long-range Energy Alternative Planning System, User Guide, Boston, USA, 2006.
[23] Ho-Chul Shin, Jin-Won Park, Ho-Seok Kim, Eui-Soon Shin, Environmental and economic assessment of landfill gas electricity generation in Korea using LEAP model: Energy Policy, 33, (2005), pp. 1261-1270.
[24] Qingyu Zhang, Tian Weili, Wei Yumei, Chen Yingxu. External costs from electricity generation of China up to 2030 in energy and abatement scenarios: Energy Policy, 35, (2007), pp. 4295-4304.
[25] Summary for policy makers: Renewable power generation costs, International Renewable Energy Agency (IRENA), November 2012.
[26] Md. Alam Hossain Mondal, Manfred Denich, Assessment of renewable energy resources potential for electricity generation in Bangladesh: Renewable and Sustainable Energy Reviews, Volume 14, Issue 8, October 2010, Pages 2401–2413.