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A Probabilistic Analysis of Levelized Cost of Energy (LCOE) for Bangladesh

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ABSTRACT

Energy crisis is one of the major problem for Bangladesh to eradicate extreme poverty and achieve middle-income status. Electricity production in Bangladesh is mostly from conventional energy sources like fossil fuels and natural gas. Experiencing huge shortage of electricity and realizing the future energy demand of the country, the government of Bangladesh is going to install a nuclear power plant for the large scale (2.4 GW) electricity production. A comparative study is conducted in this paper to observe the levelized cost of energy scenario for several electricity generating technologies. The present calculation is done using the LCOE simulator. From the simulation results, it is found that the distribution of levelized bus bar costs for the nuclear power plant is in the range of 11.69-17.84 cents/kWh, with a most probable value of about 14.75 cents/kWh; for coal-fired plants the corresponding values are 15.56–19.90 cents/kWh and 17.73 cents/kWh and for the combined cycle gas power plant the corresponding values are in the range of 15.90-17.30 cents/kWh and a most probable value of about 16.60 cents/kWh. Comparing the results from different technologies, it is worth saying that nuclear power plant is the best option for large scale (2.4 GW) power production for a developing country like Bangladesh.

Keywords: Energy crisis, Levelized Cost of Energy (LCOE), Combined cycle plant, Coal fired plant, Nuclear power.

1. Introduction

Energy is a fundamental building block to modern life to ensure human progress and improvement of living standards for the billions of people across the world. Global energy demand is expected to climb about 25% with an annual growth of 1.2% by 2040 [1]. Oil and natural gas will contribute nearly 60% of global supplies in 2040, while nuclear energy and renewables will grow about 50% and be approaching a 25% share of the world's energy mix [2]. Bangladesh is one of the most arousing energy growth countries in the world. The government of Bangladesh is working hard to eradicate extreme poverty and achieve middle-income status by 2021. Still, per capita energy consumption in Bangladesh is only about 407 kWh which is much lower than the world average (2200 kWh) and lower than the developing countries (650 kWh) around the world [3]. Socio-economic development is unconceivable unless otherwise the energy demand of a country is met properly. Electricity is the prime source of power that can boost the development process. Bangladesh produces most of its electricity from the conventional energy sources like gas, coal, oil etc. Around 66% of the commercial energy consumption is based on natural gas. Bangladesh has one National Grid with an installed capacity of 13,555 MW as on June' 2017 (Fig.1).

While current installed capacity is 13,555 MW as of February, 2017, there is a shortfall due to mismatch between fuel mixes and plant types as well as poor distribution infrastructure. As a result, only two-thirds of Bangladesh's population is currently connected to the electricity grid. According to the Power System Master Plan (PSMP), power demand in Bangladesh is projected to hit 38,000 MW by 2030 (Fig. 2). The government of Bangladesh plans to increase power generation capacity beyond projected demand to 39,000 MW by 2030 to propel a fast-growing export-oriented economy that will also likely include greater domestic consumption. To achieve the sustainable energy development and improvement of life index by increasing per capita energy consumption, Bangladesh is giving the utmost priority on large scale power production. Bangladesh government is now taking initiatives to generate electricity from nuclear power plant to keep pace with the increasing energy demand by taking a project on hand called Rooppur Nuclear Power Plant Project (RNPP). Assessment of relative energy cost generating from new technologies is very essential to make it acceptable among the consumer [6]. It is a complicated process for different technologies as it is dependent on several parameters having several impact. The rates of fuel cost changes for a considered power technologies during plant life time is assumed at the initial state. In reality, these changes are governed by the latent frictions in the global fuel market in the considered period [7]. The Levelized Cost of Energy (LCOE) method is an essential tool to compare the cost of energy produced by different generating technologies. The LCOE is often cited as a convenient summary measure of the overall competiveness of different generating technologies. It represents the per-kilowatt hour cost in discounted real dollars of building and operating a generating plant over an assumed financial life and duty cycle. This paper presents the average values of levelized costs of energy for different generating technologies available in Bangladesh with the brand new nuclear technology to make a comparison

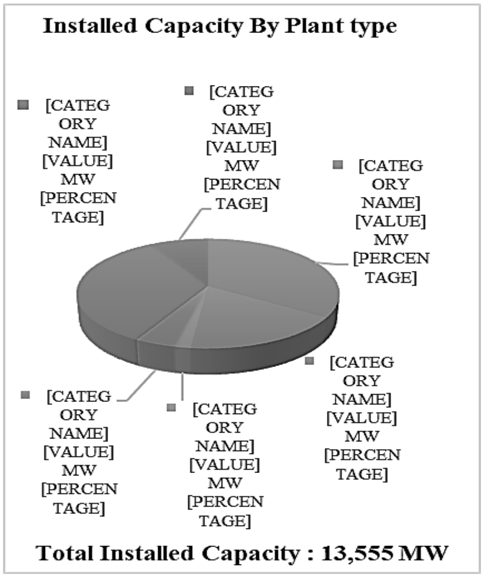

Fig. 1: Total installed capacity using different technology [4]

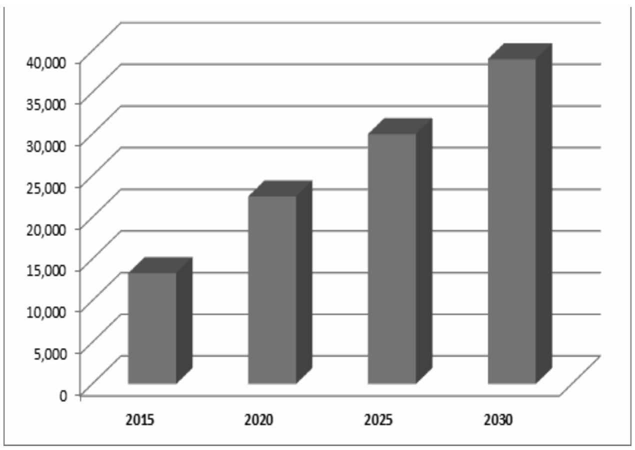

Fig. 2: Probable power demand projection of Bangladesh [5]

2. Levelized Cost of Electricity (LCOE)

Energy policies concerned with the future of energy must funnel through the price at which energy will enter the marketplace, if it is to be viable. The LCOE, as the price at the bus bar needed to cover the operating plus annualized capital costs of new generating technologies, must be competitive with prices of other base load electricity. The LCOE is often referred to as a useful tool to measure of the overall competiveness of different generating technologies [8]. There are several parameters that must be taken into account to calculate LCOE like capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type [9]. The importance of the considered parameters is different for different generating technologies. Solar and wind generation technique have no fuel costs and variable O&M costs is comparatively small hence estimated capital cost plays the key role to change the LCOE. The LCOE may be affected significantly by the fuel cost and overnight cost for certain technologies with significant fuel cost [10]. There is uncertainty about all of the parameters and their significance can vary regionally and across time as technologies evolve and fuel prices change. The availability of various incentives, including state or federal tax credits, can also impact the calculation of LCOE.

For a new project having specific technology and regional characteristics, there are other numerous factors those affect the actual plant investment decisions like the projected utilization rate and the existing resource mix in a region which are not reflected in LCOE values. Capacity value is another related factor which depends on both the existing capacity mix and load characteristics in a region [11].

The LCOE model developed by Gregory T. Forcherio from Purdue University is used for this paper that contains five major LCOE cost components:

Annuitized capital cost (A), Investment (I), fixed O&M costs (M_f), variable O&M costs (M_v), and fuel costs (F). The LCOE is such that a charge per kWh of this amount over the life of the plant will give present value of revenues just equal to the present value of the cost of constructing the plant and operating it over its life [12]. With the help of the study conducted at the University of Chicago, August 2004, the selected parameters important to determine the levelized cost of any energy producing technology have been taken into consideration and a comparative study has been done among natural gas, coal and nuclear technology.

3. LCOE model and data analysis

The levelized cost is that value for which an equal-valued fixed revenue delivered over the asset's generating profile would cause the project to break even. This can be roughly calculated as the net present value of all costs over the lifetime of the asset divided by the total electricity output of the asset. The LCOE calculated by taking into consideration of all the expenses those are experienced throughout the plant lifetime like construction period, operational lifetime and decommissioning costs. The LCOE of any generating technology with respect to various costs items can be obtained from Equation (1) [13],

$$LCOE = \frac{\text{sum of cost over lifetime}}{\text{sum of electrical energy produced over lifetime}}$$

Or,

$$\mathrm{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \qquad (1)$$

Where I_t= investment expenses in the year t; M_t= operational and maintenance costs in the year t; F_t = fuel costs in the year t; E_t= electrical energy generated in the year t; r = discount rate and n = power plant life time. To estimate the LCOE value and the competitiveness of the nuclear technology with other existing generating technology, we used the technical and cost data according to the recent studies named "The future of Nuclear Power" (2003) and "Updated on the cost of Nuclear Power" (2009) conducted by Massachusetts Institute of Technology. **Table 1**, shows the technical and costs data for nuclear, natural gas and conventional coal technology.

Table 1: Technical assumptions for different sources. Kilowatt-hour (kWh) refers to the electricity output of the power plant [14-17]

Parameters	Units	Nuclear	Natural gas	Coal
Capacity factor		90%	85%	85%
Overnight cost	$/kW	3000	600	2000
Incremental capital cost	$/kW/year	40	10	27
Fixed O&M costs	$/kW/year	63	13	24
Variable O&M costs	$mills/kWh	0.47	0.41	3.57
Fuel costs	$mills/kWh	6.968	15	12.5
Waste fee	$/kWh	0.001	-	-
Decommissioning cost	$ million	700	-	-
Fuels carbon intensity	Kg-C/kWh	-	0.099	0.229
Construction period	Years	10	4	5
Plant life	years	60	40	40

From **Table 1**, initial assumptions for various generating technologies can be visualized in terms of both similarity and dissimilarity. Construction period is different for different technology but plant life is considered same for all for our research. From the current research regarding nuclear technology [18-22], it is seen that life time of nuclear power plant may be extended up to 60 years or even more depending upon the overall scenario of the existing power plant or the technology used for the newly constructed power plants.

The economic and financial assumptions are given in **Table 2** for nuclear technology and for fossil sources according to MIT, Cambridge, US [14-15].

Table 2: Economic assumptions for nuclear technology and fossil fuel [14-15, 23]

	Nuclear	fossil
Inflation rate	3%	3%
Tax rate	37%	35%
Debt fraction	90%	50%
Debt terms (years)	28	15
Debt rate	4%	8%
Equity rate	15%	18%

Table 3: LCOE in cents/kWh for nuclear, natural gas and coal technology considering 10% discount rate

Operational Period	LCOE (nuclear)	LCOE (natural gas)	LCOE (coal)
5	17.84	17.30	19.90
10	13.99	16.47	17.19
15	12.80	16.23	16.35
20	12.26	16.12	15.97
25	11.99	16.06	15.78
30	11.83	16.02	15.67
35	11.74	16.01	15.60
40	11.69	15.90	15.56

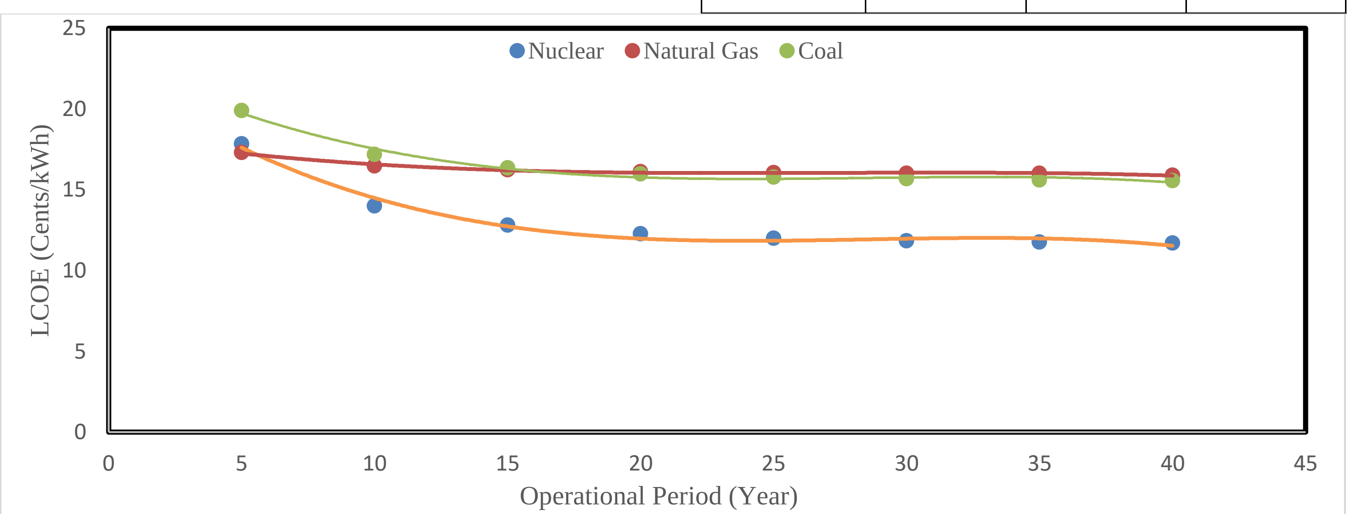

Fig. 3: Levelized cost for different generating technologies

After determining all the necessary parameters for the LCOE calculator, we proceed to run the simulation. We run the simulation for three different generating technologies to find out the levelized energy cost as well as to make a comparison between them. **Table 2**, shows the necessary economical assumptions for nuclear and non-nuclear technologies and **Table 3** shows the simulation results. The overnight cost for different technologies those are considered for our simulation is one of the key parameters to affect the levelized bus bar cost of electricity. Nuclear and coal sources are highly dependent upon the uncertainty of this parameter. Levelized bus bar cost can be affected in a significant amount for any unpredictable cost variations. To reduce such risk associated with overnight cost, a well - structured financial operations appealing at project financing can be used. In case of natural gas, uncertainty in the fuel cost can play a vital role to determine the levelized bus bar cost. The heat rate is considered 10000 Btu/kWh for all of the three generating technology. From the previous studies [24], it is seen that 9% discount rate has been considered as the baseline and 6% and 12% are considered as the low and high discount rate respectively. In our case, 10% discount rate is considered to run the simulations.

4. Results

From the current scenario, it can be concluded that the levelized bus bar cost of electricity generation at the initial state of power plant life, is maximum (19.9 cents/kWh) for coal and minimum (17.3 cents/kWh) for natural gas (Fig. 3). For nuclear power plant it is found to be 17.84 cents/kWh. As the power plant gets older, the bus bar cost of nuclear technology becomes more favorable than the other two. All the safety and security issues must be maintained properly as it was at the beginning of operation. To do so, monitoring and maintenance is a routine work for every NPP. Although plant life time considered here is 40 years for all the three generating technology but in recent practice, a significant number of nuclear power plants are expected to extend their life time up to 60 years [20]. If it happens, then the bus bar cost of nuclear power plant will be more favorable than it is right now. Under the economic standpoint, nuclear technology is not highly favorable if the safety and security perspectives is maintained high [25]. It is because nuclear safety is far more sensitive than any other existing technology. Another reason that makes nuclear technology competitive to other technology is its higher overnight costs and long construction periods. If the discount rate is high, then the LCOE value of nuclear technology will be higher than the coal or natural gas generating technology. For low to baseline discount rate, nuclear generating technology becomes competitive with fossil fuel generation. The amount of debt issued, debt term and debt rate have some effect on the levelized generation cost of electricity in case of nuclear power plants but natural gas is quite stable with respect to the debt issues [8]. High Level Wastes (HLW) generate in an NPP is another major concern because of its requirement of highly expensive management and disposal process. In case of Rooppur NPP, HLW mainly spent fuel will be taken back by the Russian Federation after a short span of storage on the spent fuel pool [26]. The international practice of waste management fee is given in Table. 1. The nuclear technology will be more competitive if the cost of carbon emission is taken into account [27-30]. Also, the global effort to reduce green - house effect is playing an important role to boost the power production tendency from a clean energy source like nuclear.

5. Conclusion

The levelized Cost of Energy (LCOE) simulator is one of the best tools to estimate the bus bar generation cost of any new generating technology and to measure the competitiveness of the new comer with the existing ones. It is very flexible to assess the economic and financial aspects those can affect the generating cost. From the present study, it can be concluded that the nuclear technology has enormous potentiality in the current market context regardless of its higher overnight costs and highly sensitive safety issues. The LCOE value of nuclear technology may be affected by the costs met during construction periods but the market role is involved with the whole generation process like construction phase to operation and decommissioning at the end of the life-cycle. Considering the present shortcomings of energy supply to the future demand of energy for Bangladesh, it is essential to take steps to large scale power production. In the current energy mix of the country, dependency upon the natural gas must be reduced to strengthening the fuel reservation. In the meantime, the global community is seeking energy diversity avoiding coal because of its large scale contribution to green -house effects. In this context, nuclear technology is the only possible way to meet the large scale power production criteria while keeping the carbon emission as low as possible. From the simulation results under given conditions and without considering external costs, it can be concluded that nuclear technology is the best suited option for Bangladesh to go large scale (2.4 GW) power production to meet the present and future energy demands of the country.

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