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Cost-Benefit Analysis of Advanced Metering Infrastructure of Smartgrid: A Case Study of Dhaka City

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Abstract: The aim of this research is to present a methodological approach to obtain the cost-benefit impact at environmental and socioeconomic level, related to the integration of advanced metering infrastructure (AMI) into utilities and their residential customers. The methodology used to quantify the costs and benefits of implementing such technology in smargrid domain at Dhaka city. The socioeconomic benefits estimated in this research were related to job creation, energy consumption decrease, reduction of non-technical losses, and the reduction of CO_2 emissions. An economic analysis using the net present value is presented here for assessing the impact caused by smart metering implementation. Also, sensitivity is analyzed for energy price, AMI cost and duration of the project. The result shows that AMI system implantation has advantages over current situation.

Keywords: Advanced metering infrastructure, smart meters, smartgrids, cost-benefit analysis, net present value.

1. INTRODUCTION

The issue in Dhaka, Bangladesh, is not a shortage of energy access. Instead, the problem is the amount and quality of energy that is currently accessible compared to the rising demand in an urban region where there will be 20 million people by 2021. When energy supply and demand are out of balance, power outages can occur, which prompts the usage of dirty diesel generators as a backup in residential areas or on industrial locations.

One of the top power distribution companies in Bangladesh, Dhaka Power Distribution Company (DPDC), was the first to begin efforts to implement the SG system in Dhaka and Narayanganj. At the end of December 2022, the DPDC's first pilot project, dubbed the introduction of the smart grid, will begin its implementation phase. The pollution produced by diesel generators used as a backup during grid failures will be eliminated when the smart grid enhances grid performance. The quality of the electrical service will significantly increase, benefiting 1141000 people in total. The project also mitigates climate change by avoiding an annual accumulation of 104,000 tons of CO_2 emissions [1].

Overall, and not just including the project with the DPDC, the smart grid solution is of great operational value. It makes it possible to carry out maintenance upstream of failures and to optimize the use of equipment like power transformers, circuit breakers, etc. This is made possible by real-time algorithms that continuously analyze the hardware connected to the grid and thus extend its life. The digital presence at all levels of the network allow for better knowledge of the network and anticipation of outage-related events. The smart grid gives us a more reliable, accessible grid.

Compatibility and interoperability issues should be low because DPDC operates in accordance with international standards and employs cutting-edge technical principles. This implies that various equipment types from various manufacturers will be able to connect with one another and carry out sophisticated automation tasks. The worldwide standard IEC 61850 is based on this fundamental tenet. This strategy is not unique to Bangladesh. Even if it requires modifying a few communication units to make the entire system remotely interoperable, existing equipment can be incorporated into creative and technologically advanced solutions.

It goes without saying that any electric company that wants to achieve its primary objective of supplying reliable and adequate electricity must incorporate digitization and digital technology into the solutions it provides. This transition takes shape thanks to the smart grid, which boosts the grid's effectiveness and efficiency. Additionally, by incorporating digital technology into our projects, we hasten the uptake of renewable energy sources and so help the nation achieve its Sustainable Development Goals (SDGs).

Installing a Smart Metering (SM) system is one of the key prerequisites for converting to an SG system. [2]. As a first step to implementing the SG system in Bangladesh, the government of Bangladesh has been planned to phase-in the installation of 8.8 million smart prepaid meters across the entire nation, according to the ministry of power, energy, and natural resources. The installation of 2226600 meters by power distribution companies for the fiscal year 2020–2021 has been set as a goal for carrying out this plan. By FY 2020–21, companies like Bangladesh Power Development Board (BPDB), Bangladesh Rural Electrification Board (BREB), Dhaka Power Distribution Company Limited (DPDC), Dhaka Electric Supply Company Limited (DESCO), West Zone Power Distribution Company Limited (WZPDCL), and Northern Electric Supply Company Limited (NESCO) will install these meters, totaling 1100000, 250000, 200000, and 400000 respectively [3].

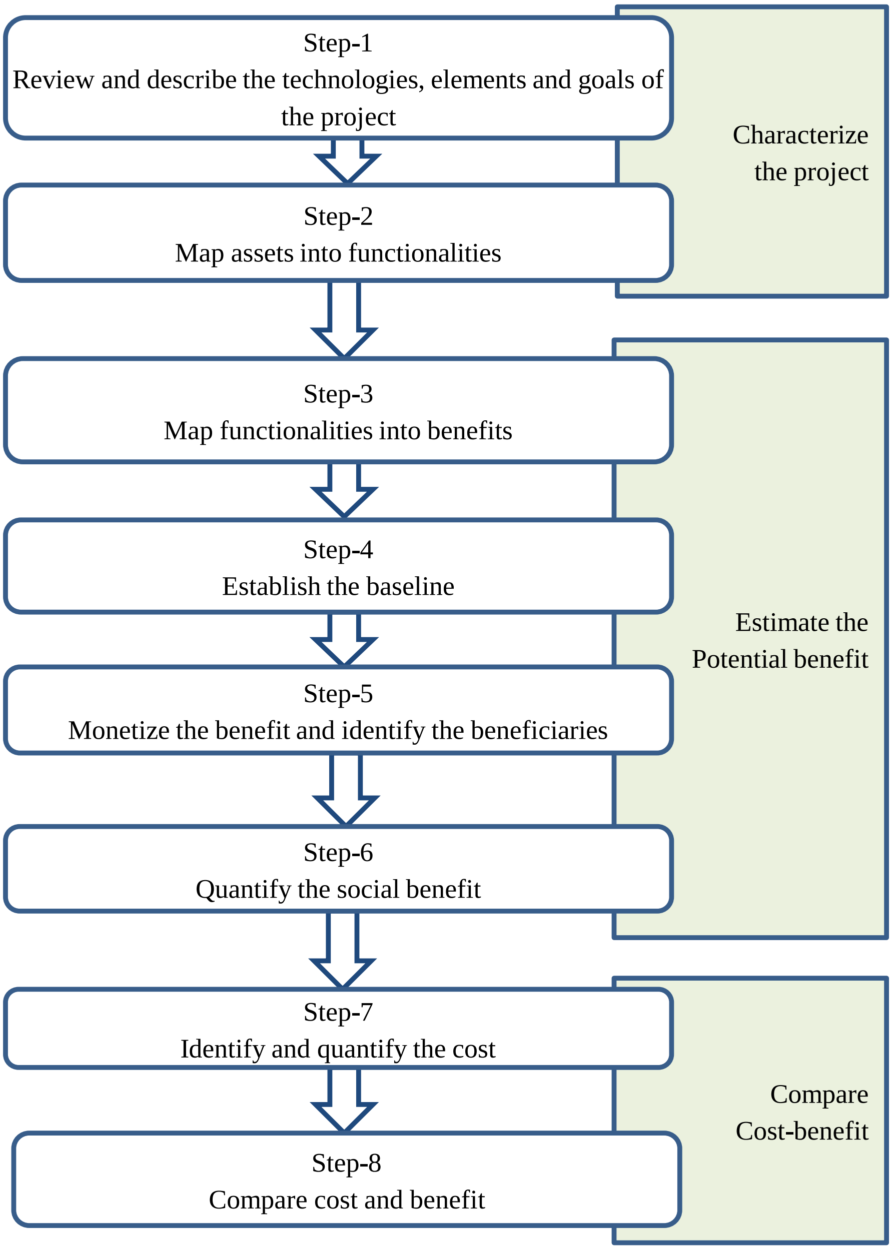

Figure 1. Cost-benefits methodology for implementing advanced metering infrastructure

2. DHAKA POWER DISTRIBUTION COMPANY LIMITED (DPDC)

The Dhaka Power Distribution Company Limited (DPDC) is a public limited company that falls under the authority of the Power Division of the Ministry of Power, Energy, and Mineral Resources of the Government of Bangladesh. It is responsible for overseeing the distribution of electricity to the residents of the Dhaka City Corporation region. The firm was registered on October 25, 2005, in accordance with the Companies Act of 1994, as a result of the Power Sector Reform Program. The corporation is entirely owned by the government. On July 1, 2008, DPDC began doing business, replacing the Dhaka Electricity Supply Authority (DESA). A contract agreed in September 2008 saw the transfer of all of DESA's assets and liabilities to DPDC [4].

3. DHAKA ELECTRIC SUPPLY COMPANY LIMITED (DESCO)

The public limited company Dhaka Electric Supply Company Limited, also known as DESCO, provides energy to Tongi Town in the Gazipur District and the northern areas of Dhaka City. As a Public Limited Company, the business was established in November 1996 in accordance with the Companies Act of 1994. As of December 31, 2013, the corporation served 604,304 users overall and was now a part of the Power Division of the Bangladesh Ministry of Power, Energy, and Mineral Resources [5].

4. METHODOLOGY

This study's technique was adapted from a reference [6-7]. This methodology offers a simple, step-by-step process for analyzing the costs and benefits of a smart grid project. The proposed methodology was then implemented in stages to a local smart metering project in the city of Dhaka.

The study's approach is depicted in Figure 1 in order to determine the economic and environmental effects of integrating smart meters into the city of Dhaka's electrical network. The analysis was separated into the three sections below: Descriptions of the projects, a cost-benefit analysis, and an estimate of the possible advantages.

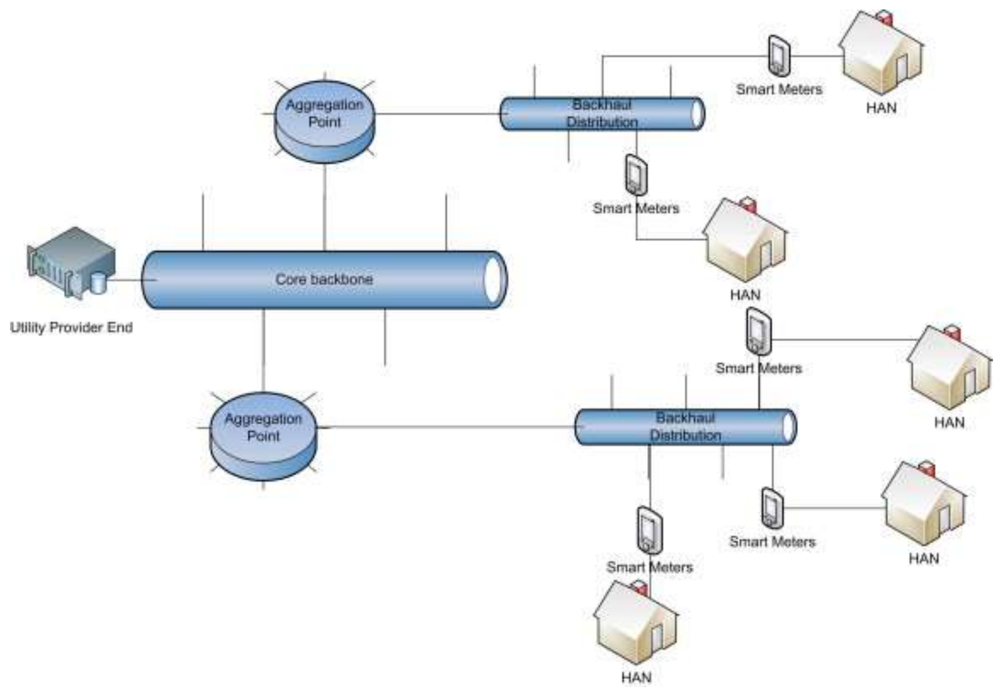

Figure. 2 Advance metering infrastructure

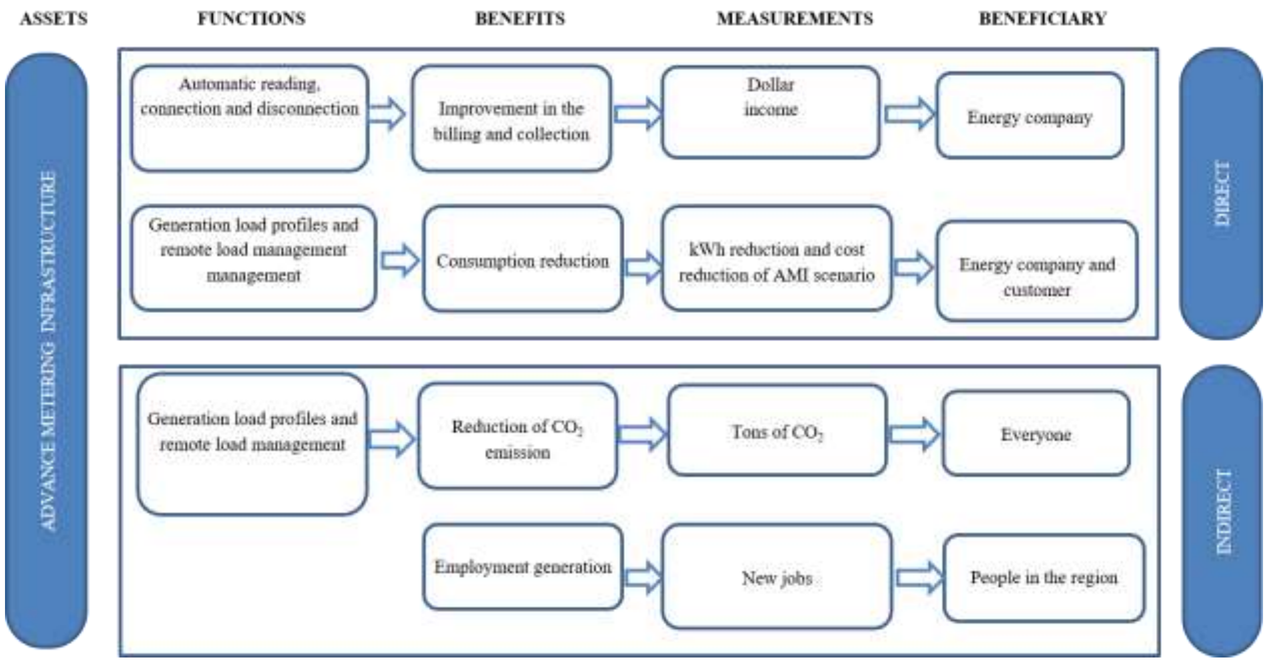

Figure 3. Map features and benefits attributed to smart metering.

5. PROJECT CHARACTERISTICS

For local utility household users, this project entails the installation and subsequent operation of 3585277 smart meters. The apparatus would have to function under the two-way automatic communication system-based AMI communication architecture. Data from the meters is transmitted by electrical distribution lines to equipment at the substation, where it is then transferred to the control centers using different communication technologies. The AMI infrastructure is composed by two levels shown in Fig.2 [8].

Level 1: Equipment's of Substation communications

Level 2: Equipment Remote communications

6. MAP FUNCTIONALITIES TO BENEFITS

The process of turning smart metering's functions into advantages is defined in this research as beginning with general features that include energy price, load management, demand curve management, energy losses, annual employment, and CO_2 emission reduction.

The functionality to benefits map created in this work is shown in Figure 3 [6]. Each benefit identifies a metric that measures achievement and the recipients.

7. ESTABLISHING THE BASELINE

To compare the new scenarios—the AMI scenario—with the current situation and determine the difference between the generated costs and benefits, the project baseline must be established. The baseline scenario in this work is the conventional measurement method based on electromechanical meters. There are two scenarios included in this work. Each of them is described as follows:

- Current Situation: As of present now, electromechanical meters are being used to measure energy use.
- AMI Scenario: Smart meter implementation, remote load connection and termination, and detection of unwanted tampering are all included in the AMI Scenario

8. MONETIZE BENEFITS

A numerical simulation program was used to monetise and interpret the advantages shown in Figure 3 for the specific location. The calculation creates new energy measuring scenarios by taking into account a hybrid communication infrastructure made up of a meter and GSM connection from a data concentrator to a utility. The tool was changed to take into account the local utility's adoption of the AMI system's infrastructure.

The main pertinent variables, equations, and presumptions that were used to quantify the costs and monetize the advantages of deploying the new energy measurement system in the city of Dhaka are shown in Tables 1 and 2. An rise in both the number of consumers and the inflation rate were taken into account when estimating the annual costs and benefits.

Table 1. Input parameters

Parameter	Value
1. Smart meter cost	200 USD
2. Cost of electromechanical meter	80 USD
3. Annual increase in number of electricity customers	2%
4. Cost per day of hiring a human meter reader	20 USD
5. Average percentage of electricity lost as a result of local utility fraud	12%
6. Using smart meters has resulted in an average decrease in the amount of electricity fraud.	7%
7. Average drop in power use under the AMI Scenario	2%
8. Discount rate	5%
9. Energy fee per kWh	0.025USD /kWh
10. Average monthly consumption of customers	300 kWh

Table 2. General Equations considered in the model

Variable	Equation
1. Remote meter reading cost (USD)	Number of meters × Annual reading frequency × Payment for each manual reading
2. Non-Technical losses cost (USD)	Total number of consumers × Energy fee (USD/kWh) × Total average annual consumption (kWh) × Estimated average percentage of non-technical losses
3. CO_2 emissions cost (USD)	Total consumer × Unit consumption yearly (kWh) × Emission (g/kWh) × Value of emission (USD/g)
4. O/M maintenance costs (USD)	Total number of meters × O/M cost/meter (USD)
5. Employee cost (USD)	Total employer × employer salary per year (USD)
6. Revenue calculation	Total consumer × consumption per consumer (kWh)× price per unit (USD/kWh)

9. REMOTE METER READING COSTS

When compared to the current scenario, new sophisticated metering technology considerably reduces the costs associated with meter reading, as demonstrated below in Figure 4. The primary explanation is because these gadgets allow for remote task execution through long-distance connection. The technology's capacity to remotely detach and reconnect individuals when necessary is an additional intriguing feature. In the sixth year, when the whole system is deployed, the graph demonstrates that implementation costs reach their lowest point. It is important to note that in a market where prices are competitive, cost savings may be passed on to the customer.

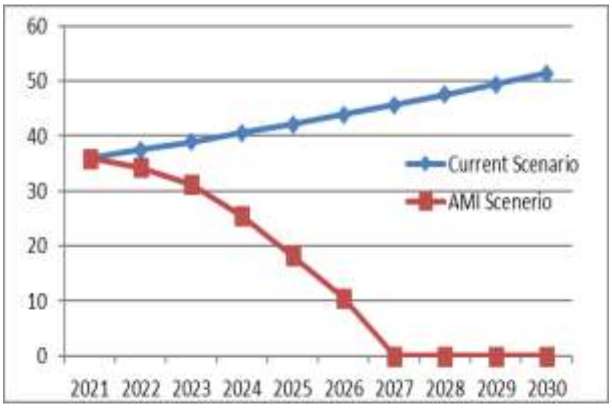

Figure 4. Remote meter reading costs in USD (millions)

10. NON-TECHNICAL LOSSES REDUCTION

The substantial non-technical losses in the local utility's network are one of the primary drivers for the adoption of the new smart metering infrastructure. According to the findings of the investigation, the first model year's economic losses were in the range of 40.0 million USD annually.

When compared to the current scenario, Figure 5 illustrates a significant decrease in annual operating costs as a result of the elimination of non-technical losses. Consequently, putting in place smart meters has a direct impact on increasing revenue. Savings from recovered losses are predicted to occur seven years after such adoption, when smart meters are fully implemented. As a result of three crucial elements, including market expansion, yearly inflation, and rising energy prices, Fig. 5 also depicts a minor increase in expenses towards the conclusion of the implementation period while maintaining a consistent percentage of non-technical losses.

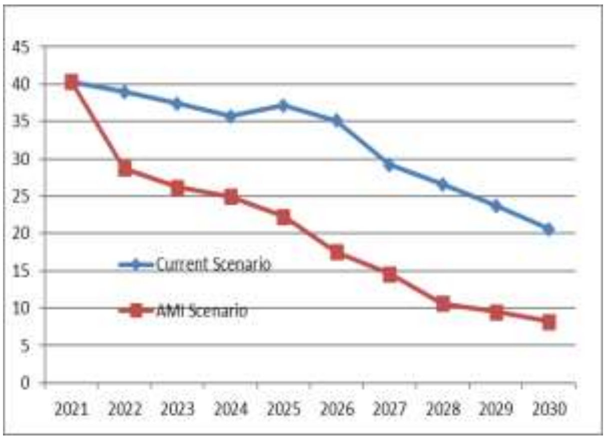

Figure 5. Non-technical losses costs in USD (millions)

11. REDUCTION OF CO_2 EMISSIONS

A methodology for estimating emissions that is given in Table 2 is used to assess the reduction in CO_2 emissions caused by the use of smart meter technology in the city of Dhaka. Such a methodology took into account the average CO_2 emission rate of 10g/kWh related to energy generation in Dhaka as well as annual customer electricity use. The anticipated annual reduction in CO_2 emissions for the AMI scenario is shown in Figure 6. The country as a whole, especially those areas where power is generated by thermo-plants, will benefit from the consumption information that is reducing CO_2 emissions, not just the metropolis. It is critical to emphasize that Dhaka's CO_2 emissions are quite high when compared to those of other nations.

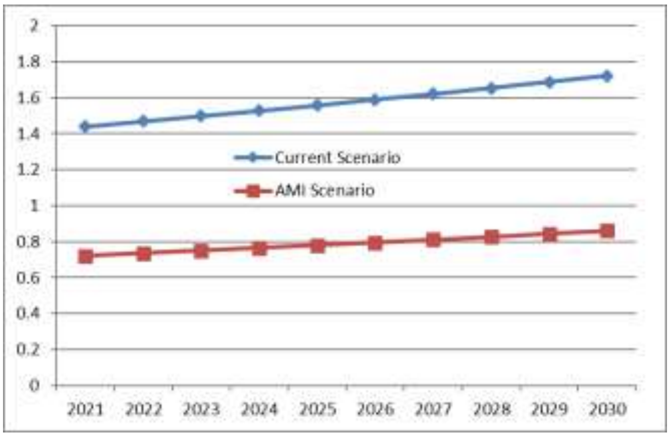

Figure 6. Cost of CO_2 in USD (millions)

12. METER INSTALLATION COST

The results for annual installation costs are displayed in Figure 7 below in order to predict installation costs for new smart meter technology.

Due to the enormous expense of integrating smart meters, a steady increase in costs can be seen during the first seven years of deployment (2021–2027). Since electronic equipment are frequently negatively impacted as time goes on, a 5% reduction in the cost of smart meters is estimated in this scenario.

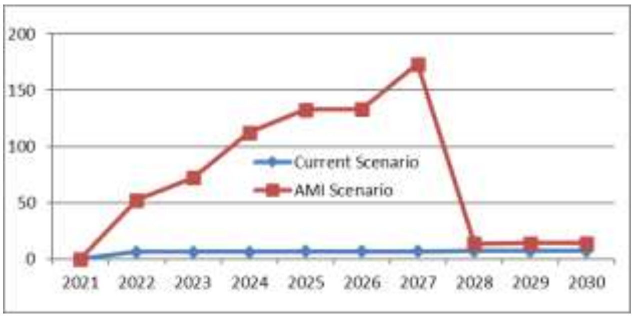

Figure 7 Installation costs of equipment in USD (millions)

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13. EQUIPMENT OPERATION AND MAINTENANCE COST

This study used the 1.5% failure rate for smart meters available in the literature to calculate maintenance costs. It is presumed that 1%, as reported by the local utility, applies to the current situation. The first is the cost of adopting AMI during the first seven years of the program, which accounts for the majority of the cost difference between the current situation and the AMI scenario. The second factor is brought on by the cost distinction between electromechanical and smart meters, as well as the latter's higher failure rate.

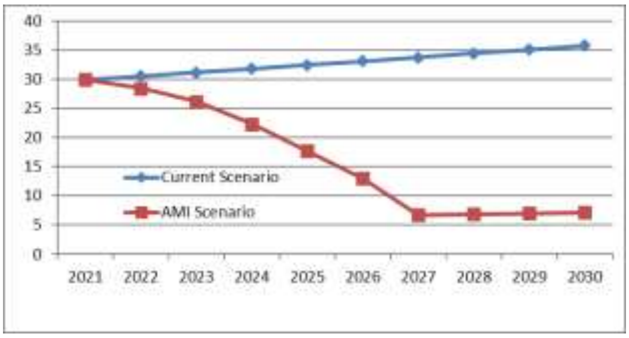

Figure 8. Equipment operation and maintenance cost in USD (millions)

14. EMPLOYEE COST

Social aspects of the implementation of smart meters include job creation or personnel costs. Evaluating the project's impact on employment is one activity that poses significant hurdles. When comparing the AMI to the current situation, Figure 9 demonstrates a detrimental effect on job development. The primary reason is that AMI does away with manual readings and the requirement for staff to perform local connection and reconnection, which can be accomplished remotely with smart meter technology. Utility companies can lower their labor needs while lowering operating expenses thanks to such initiatives.

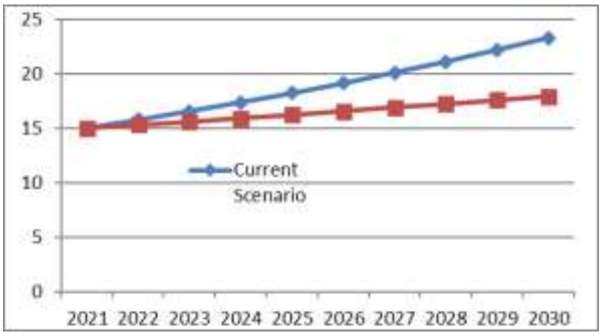

Figure 9. Employee salary cost in USD (millions)

Figure 9 demonstrates that only in the first seven years of the model, as compared to the present, more jobs are created under the AMI Scenarios. The graph's incremental peaks are caused by the potential need for several installations in order to roll out the new technology. Although the creation or destruction of jobs has a detrimental influence on society, process automation benefits utilities financially.

15. COST BENEFIT COMPARISON

The approach proposes three ways to compare costs and benefits once they have been assessed in order to assess the project's cost-benefit ratio. The three techniques are as follows: Net present value, annual comparison, and cumulative comparison (NPV). The net present value approach was used in this study. Due to the replacement cost of the AMI, Figure 10 depicts a higher project cost for the AMI scenario before 2028.

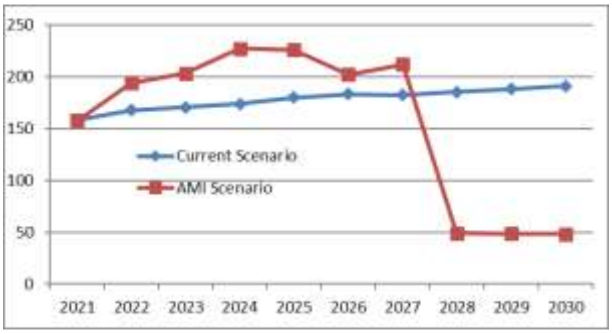

Figure 10. Total cost of project in USD (millions)

Due to savings, Table 3 displays a positive net present value for customers. Savings depend on consumers managing their spending patterns more effectively. However, it's crucial to remember that saving rates are modest and heavily influenced by a customer's sociocultural upbringing. The above is backed up by a significant decrease in non-technical losses. Both scenarios have a positive value and are successful. However, the AMI scenario has a higher NPV and benefit-cost ratio. Therefore, AMI is more profitable in comparison.

Table 3 Current and AMI scenario comparison

Particular	**Current Scenario**	**AMI Scenario**
Present value of cost (Million USD)	1665.86	1562.34
Net present value (Million USD)	156.52	197.90
Benefit-cost ratio	1.14	1.43

16. SENSITIVITY ANALYSIS

Finding the range of factors that can result in a favorable outcome in the cost-benefit analysis is the aim of the sensitivity analysis. To do this, it is important to determine the values of the critical variables that must be commutated, i.e., the value at which the NPV would be zero or, more generally, the project's outcome would not be below a predetermined minimum acceptable level. After 7 years, we gain from Table 4. This is for the price of installing a meter. As demonstrated in Table 5, the benefit is sensitive to the cost of the AMI. Energy cost sensitivity is also examined. As seen in Table 6, if energy prices decrease, this project won't be profitable.

Table 4. Sensitivity analysis according to year

Year	Benefit-cost ratio		Net present value (Million USD)	
	Current scenario	AMI Scenario	Current scenario	AMI scenario
7	1.01	0.85	11.600	-198.344
10	1.10	1.14	156.523	197.890

Table 5 Sensitivity analysis for AMI Cost

AMI Cost (USD)	Total Cost	Net present value (Million USD)	Benefit-cost ratio
300	1425.127	-79.680	0.94
270	1286.342	59.105	1.04

Table 6. Sensitivity analysis for energy cost (USD/kWh)

Energy cost (USD/kWh)	Benefit-cost ratio		Net present value (Million USD)	
	Current scenario	AMI Scenario	Current scenario	AMI scenario
0.020	0.89	0.92	-156.48	-120.77
0.022	0.98	1.01	-31.28	6.70
0.025	1.11	1.14	156.52	197.89

17. CONCLUSIONS

The engineer is able to estimate the costs and value the economic and environmental advantages that smart meters bring to the city of Dhaka thanks to the presented technique. Reduced CO_2 costs will have a favorable influence from a societal standpoint. Although the new metering infrastructure offers technology benefits like remote reading, remote connection, and remote disconnection that significantly reduce the requirement for personnel, it may have a negative effect on employment. Due to reduction of consumer electricity and non-technical loss, the monthly bill will be comparatively low under smart-grid environment. Benefit-cost ratio is very sensitive to AMI installation cost, energy price and duration of the project. So, forecasting of the value with lower error is necessary to analyze the project in smart grid domain and this may be considered for further evaluation in future study.

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