International Journal of Advanced Trends in Multidisciplinary Research
ISSN: 3139-0986, Volume 2 Issue 8
Aug 2026, PP 1-4

Economic Valuation of Bagasse-Based Cogeneration in Bangladesh Sugar Mills: The Avoided Cost and Strategic Replacement Value of Quick-Rental Power

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***Abstract* – Bangladesh's sugar industry possesses an under-recognized indigenous energy asset in the form of bagasse-based cogeneration. Bagasse, the fibrous residue generated during sugarcane crushing, is traditionally combusted in boilers to produce process steam and electricity for sugar-mill operations. This study develops an avoided-cost framework to estimate the economic value of bagasse-based electricity generation associated with sugar mills under the Bangladesh Sugar and Food Industries Corporation (BSFIC). Previous studies have documented 14 bagasse-based cogeneration plants in Bangladesh with a combined historical installed capacity of approximately 38.1 MW, while engineering assessments have identified potential surplus export capacity of approximately 3–4 MW per mill under suitable operating conditions. Using an analytical capacity range of 42–49 MW, with a central estimate of 45.5 MW, and a 40% capacity factor, annual electricity generation is estimated at approximately 159.4 GWh. Using the historical Bangladesh Institute of Development Studies (BIDS) benchmark of Tk 11.97/kWh for quick-rental electricity, the equivalent avoided conventional-generation expenditure is approximately Tk 1.91 billion (Tk 190.8 crore) per year. A seasonal scenario of 135 operating days and 22 hours per day produces approximately 135.1 GWh and an equivalent replacement expenditure of approximately Tk 1.62 billion (Tk 161.8 crore). These figures represent gross avoided generation expenditure rather than direct government savings, because actual net economic benefits require deduction of operation and maintenance costs, biomass opportunity costs, capital recovery, and grid-integration costs.**

***Keywords* – Bagasse; Sugarcane; Cogeneration; Biomass Energy; BSFIC; Quick-Rental Power; Avoided Cost; Renewable Energy; Bangladesh; Energy Security.**

I. INTRODUCTION

Bangladesh has experienced rapid growth in electricity demand over the last two decades. To address electricity shortages and maintain supply reliability, the country has historically relied on public-sector generation, independent power producers, rental power plants, quick-rental power plants, and imported electricity.

Quick-rental power plants were introduced primarily as a rapid-response mechanism to address short-term electricity shortages. Although they provided important capacity during periods of supply constraints, their relatively high generation costs created economic and fiscal concerns. An economic appraisal by the Bangladesh Institute of Development Studies (BIDS) estimated the average total unit cost of quick-rental electricity at Tk 11.97/kWh.

At the same time, Bangladesh possesses a geographically distributed biomass-energy resource embedded within its sugar industry. Sugarcane crushing generates bagasse, which can be burned in boilers to generate steam and electricity. Previous assessments documented 14 sugar-mill cogeneration plants with a combined historical installed capacity of approximately 38.1 MW.

Engineering assessments of BSFIC mills have also indicated that modernization could enable approximately 3–4 MW of surplus electricity export per mill.

The central research question is: What is the economic replacement value of electricity generated from sugar-mill bagasse if the alternative were to supply equivalent electricity from conventional or quick-rental generation?

Research Objective

The study aims to:

- Estimate the aggregate electricity-generation capacity represented by 14 BSFIC sugar mills.
- Estimate annual electricity generation under alternative operating assumptions.
- Calculate equivalent replacement expenditure using a documented quick-rental generation-cost benchmark.
- Distinguish gross avoided generation expenditure from net economic savings.
- Assess the strategic value of sugar-mill cogeneration for energy security and renewable-energy transition.
- Identify policy measures for modernising and integrating sugar-mill cogeneration into the national electricity system.

II. LITERATURE REVIEW

Bagasse is the fibrous residue remaining after sugarcane stalks are crushed and juice is extracted. It is particularly suitable for industrial cogeneration because it is generated at the same location where heat and electricity are required. Mondal and Denich reported that Bangladesh had 14 sugar-mill-based cogeneration plants using bagasse, with a total historical power-generation capacity of approximately 38.1 MW. Other Bangladesh-focused assessments have identified approximately 50 MWe of potential from sugar-mill bagasse.

BUET-based analysis highlighted the modernisation potential of BSFIC mills and estimated that individual mills could potentially export approximately 3–4 MW of surplus electricity to the grid under improved conditions.

International literature also indicates that modern high-pressure boilers and condensing-extraction steam turbines can substantially increase electricity generation from sugar factories.

III. CONCEPTUAL FRAMEWORK

The economic framework is based on avoided generation cost:

Avoided Generation Cost = Bagasse Electricity Generated × Alternative Generation Cost

However, this gross value is not equivalent to net financial savings. The appropriate formulation is:

- Net Economic Benefit = Avoided Conventional Generation Cost − Cogeneration Economic Cost
- Cogeneration economic cost includes biomass opportunity cost, operation and maintenance, labour, boiler and turbine maintenance, depreciation/capital recovery, auxiliary electricity, water treatment, transportation and handling, grid interconnection, and other relevant costs.

IV. DATA AND METHODOLOGY

Historical literature reports approximately 38.1 MW of installed bagasse-based cogeneration capacity across 14 mills. Engineering assessments indicate potential surplus export capacity of approximately 3–4 MW per mill.

Thus, the analytical equivalent capacity range is:
14 × 3.0 MW = 42 MW
14 × 3.5 MW = 49 MW
Central estimate = 14 × 3.25 MW = 45.5 MW

The latter is an analytical equivalent capacity scenario, not an audited present-day installed capacity.

V. ELECTRICITY GENERATION SCENARIOS

Annual generation is calculated as:
E = C × 8760 × CF
For the central estimate of 45.5 MW at a 40% capacity factor:
45.5 × 8760 × 0.40 = 159.432 GWh/year.
Thus, the central annual generation estimate is 159.43 GWh/year.

Seasonal Generation Scenario
A seasonal scenario uses 135 operating days and 22 hours per day:

45.5 × 135 × 22 = 135.135 GWh.

Thus, the seasonal scenario produces approximately 135.14 GWh.

Quick-Rental Electricity Cost Benchmark
The BIDS study, Quick Rental Power Plants in Bangladesh: An Economic Appraisal, reports an average total cost of Tk 11.97/kWh for quick-rental electricity. This is a historical benchmark, not a claim about the current 2026 marginal generation cost.

Avoided Generation Expenditure
For the central annual scenario:
159.432 million kWh × Tk 11.97/kWh = Tk 1,908.4 million or approximately Tk 190.84 crore per year.
For the seasonal scenario:
135.135 million kWh × Tk 11.97/kWh = Tk 1,617.6 million or approximately Tk 161.76 crore per year.
10. Capacity Sensitivity
At 40% capacity factor and Tk 11.97/kWh:
42 MW → 147.17 GWh → Tk 176.16 crore/year
45.5 MW → 159.43 GWh → Tk 190.84 crore/year
49 MW → 171.70 GWh → Tk 205.54 crore/year

Therefore, the analytical replacement-value range is approximately Tk 176–206 crore/year.

VI. HISTORICAL INSTALLED-CAPACITY BENCHMARK

Using the historical 38.1 MW capacity:
38.1 × 8760 × 0.40 = 133.60 GWh/year.

At Tk 11.97/kWh, the equivalent replacement value is approximately Tk 159.9 crore/year.

This conservative benchmark is useful because it avoids overstating existing physical capacity.

Why Avoided Cost Is Not Fiscal Saving
The estimated Tk 160–206 crore/year is not a direct government cash saving. Bagasse cogeneration itself incurs operation, maintenance, capital recovery, biomass opportunity cost, and other costs. Net economic benefit must therefore be calculated as avoided replacement generation cost minus the full economic cost of cogeneration.

Capital Replacement Perspective
If existing sugar-mill cogeneration capacity were unavailable, replacement capacity would require land, civil infrastructure, generation equipment, fuel infrastructure, electrical interconnection, financing, environmental compliance, construction time, and long-term operation and maintenance. Existing sugar mills already possess much of this infrastructure. Consequently, the system has a strategic replacement value distinct from accounting book value.

Energy-Security Implications
Bagasse-based cogeneration uses an indigenous agricultural residue, provides distributed generation, supports circular use of biomass, and can reduce dependence on fossil-fuel-based generation. It also creates

an opportunity for seasonal electricity supply from industrial locations close to agricultural production.

Environmental Implications
Bagasse electricity should not automatically be labelled zero-carbon. Lifecycle emissions from cultivation, transport and combustion must be considered. Nevertheless, where bagasse is an agricultural residue and replaces fossil-fuel electricity, greenhouse-gas mitigation may be significant. A Bangladesh-focused assessment has estimated substantial CO2 savings from replacing fossil-fuel-based electricity with bagasse cogeneration.

Technology Modernisation
BUET assessment indicates that many BSFIC mills historically operated with low-pressure boilers, while modern bagasse boilers can operate at substantially higher pressures. Modern high-pressure boilers and efficient steam turbines can substantially increase electricity available for export.

Policy Implications
A national Sugar-Mill Renewable Energy Modernisation and Grid-Export Programme should include:

- a mill-level energy asset database;
- annual reporting of generation, bagasse use, operating hours and grid exports;
- transparent biomass-electricity tariffs;
- modernization of boilers and turbines;
- grid synchronisation and seasonal export planning;
- concessional finance for cogeneration modernization;
- carbon accounting and verification.

Economic Significance
The central estimate indicates that 45.5 MW of analytical equivalent capacity could represent approximately Tk 190.8 crore/year in avoided conventional generation expenditure at the historical quick-rental benchmark. The conservative historical-capacity scenario indicates approximately Tk 159.9 crore/year.

These figures should be interpreted as replacement value, not audited government savings.

Ten-Year Strategic Value
Using the central estimate of Tk 190.8 crore/year, the undiscounted ten-year replacement value is approximately Tk 1,908 crore (Tk 19.08 billion). This is not an NPV; a discounted assessment requires discount rate, equipment life, degradation, capital expenditure, O&M, biomass opportunity cost and electricity-price assumptions.

Limitations
The historical 38.1 MW figure and the 3–4 MW per-mill export potential refer to different analytical concepts and periods. The Tk 11.97/kWh quick-rental benchmark is historical. Actual generation depends on cane availability, crushing duration, boiler performance, turbine efficiency, maintenance and plant load factor. The replacement technology could also differ from quick-rental generation. Therefore, the results are scenario-based economic estimates rather than audited fiscal-savings estimates.

VII. CONCLUSIONS

Bagasse-based cogeneration in Bangladesh's sugar industry has economic value beyond internal mill electricity supply. Historical evidence identifies approximately 38.1 MW of installed capacity across 14 mills, while engineering assessments identify potential surplus export capacity of approximately 3–4 MW per mill under suitable conditions. At 40% capacity factor, the analytical 42–49 MW range corresponds to approximately 147–172 GWh/year. At the historical BIDS quick-rental benchmark of Tk 11.97/kWh, the equivalent replacement value is approximately Tk 176–206 crore/year, with a central estimate of Tk 190.8 crore/year. The historical 38.1 MW benchmark gives approximately Tk 159.9 crore/year.

The strategic conclusion is that Bangladesh's sugar-mill bagasse cogeneration infrastructure should be recognised as a distributed renewable-energy asset capable of reducing the need for higher-cost conventional generation. Its value includes electricity replacement, domestic biomass utilisation, energy security, agricultural circularity, rural industrial development and potential greenhouse-gas mitigation.

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