

Converting Sugarcane Waste into Energy and Power: A Business Perspective in India

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Abstract:

Sugarcane is one of the most important commercial crops in India, contributing significantly to the agricultural economy and rural employment. During the sugar extraction process, a large quantity of fibrous residue known as bagasse is produced. Traditionally, this byproduct was either underutilized or inefficiently burnt, leading to energy wastage and environmental concerns.

With increasing awareness of renewable energy and sustainability, bagasse has gained importance as a reliable biomass fuel. It is now widely used in cogeneration systems to produce both electricity and heat energy within sugar mills. This project explores the potential of converting sugarcane waste into energy through advanced technologies such as high-pressure boilers, steam turbines, and biomass gasification.

Keywords —Bagasse, Sugarcane Waste, Biomass Energy, Cogeneration, Renewable Energy, Power Generation, High-Pressure Boilers, Steam Turbine Systems, Energy Efficiency, Sustainable Development

I. INTRODUCTION

India is one of the largest producers of sugarcane in the world, making the sugar industry a backbone of rural development and employment. Every year, millions of tonnes of sugarcane are processed, resulting in a significant amount of bagasse as a byproduct. Approximately 30–32% of sugarcane weight is converted into bagasse during crushing.

Earlier, sugar mills depended heavily on coal and grid electricity to meet their energy needs. However, with advancements in technology, bagasse is now used as a primary fuel source within the mills. This has transformed sugar factories into energy-producing units rather than just sugar-producing industries.

The concept of waste-to-energy is gaining momentum as it helps reduce environmental pollution and promotes sustainable development. By using bagasse efficiently, sugar mills can generate enough electricity to meet internal requirements and also export surplus power to the grid.

This chapter introduces the importance of bagasse as a renewable resource, highlights the need for sustainable energy solutions, and defines the objectives of this project:

- To study bagasse as a biomass fuel
- To analyze technologies used for energy generation
- To evaluate economic and environmental benefits.

II. LITERATURE REVIEW

Several research studies confirm that bagasse is a highly efficient biomass fuel due to its favorable calorific value and availability. The efficiency of energy generation depends on multiple factors such as moisture content, combustion technology, and steam parameters.

Studies show that traditional low-pressure boilers generate limited electricity and are less efficient. In contrast, modern high-pressure cogeneration systems significantly improve output and efficiency. For example, increasing boiler pressure from 30 bar to 80 bar can double or even triple power generation capacity.

Research also highlights the importance of moisture control. Bagasse typically contains 45–55% moisture, which reduces its calorific value. Drying techniques or improved storage methods can enhance energy efficiency.

From an economic perspective, studies indicate that sugar mills adopting cogeneration systems experience reduced electricity costs and increased profitability through power export. Additionally, government policies promoting renewable energy have further encouraged investment in bagasse-based power plants.

III. MATERIALS AND METHODS

SUGARCANE WASTE AND BAGASSE

Bagasse is the fibrous residue left after extracting juice from sugarcane. It is composed mainly of cellulose, hemicellulose, and lignin, making it suitable for combustion and energy generation.

The calorific value of bagasse depends largely on its moisture content. Higher moisture reduces efficiency, while dry bagasse burns more effectively and produces more heat energy.

Apart from energy production, bagasse has several industrial applications:

- Paper and pulp manufacturing
- Biodegradable packaging materials
- Particle boards and construction materials
- Biofuel production (ethanol and pellets)
- Animal feed after processing

Efficient utilization of bagasse not only reduces waste but also creates multiple revenue streams for industries.

IV. Technologies Used

Bagasse-based energy generation uses several advanced technologies:

1. Low-Pressure Cogeneration

Older systems operate at 20–30 bar pressure. These are less efficient and mainly used for internal consumption.

2. High-Pressure Cogeneration

Modern plants operate at 60–100+ bar. These systems produce more electricity and allow surplus export to the grid.

3. Biomass Gasification

This process converts bagasse into syngas using limited oxygen. Syngas can be used for electricity or converted into biofuels. It is efficient but requires higher investment.

4. Steam Turbine Systems

Steam generated in boilers drives turbines to produce electricity. Efficiency depends on steam temperature and pressure, based on the Rankine Cycle.

5. Key Performance Factors

- Moisture content
- Boiler efficiency
- Turbine efficiency
- Plant Load Factor (PLF)
- Auxiliary power consumption

V. BUSINESS PERSPECTIVE

India produces approximately 350 million tonnes of sugarcane annually, creating massive potential for bagasse-based energy production.

Sugar mills can adopt various business strategies:

- **Captive Power Generation** → reduces electricity costs
- **Power Purchase Agreements (PPA)** → ensures stable long-term revenue
- **Merchant Power Sales** → selling electricity at market rates
- **Bagasse Trading** → selling surplus bagasse

- **Renewable Energy Certificates (REC)** → additional income source

These models improve financial stability and make sugar mills energy-independent.

promising with continuous advancements in biomass technologies.

TABLE 1: ENERGY YIELD METRICS

VI. COST ANALYSIS

The financial viability of bagasse power plants depends on investment and operational efficiency.

Key Data:

- CAPEX: ₹4.9–5.6 crore per MW
- 10 MW Plant Cost: ~₹49 crore
- PLF: 45–60%
- Annual Generation: ~46,000 MWh
- Tariff: ₹4.5–₹5 per kWh

Profitability:

- Payback Period: 6–9 years
- IRR: 12–18%

Better efficiency and lower moisture content can significantly improve profits.

VII. DISCUSSION & FINDINGS

The study highlights that bagasse energy systems provide multiple benefits:

- Reduction in carbon emissions
- Lower dependence on fossil fuels
- Additional income for sugar mills
- Efficient waste utilization
- Support for renewable energy targets

Modern high-pressure systems are more efficient and profitable compared to traditional methods.

VIII. CONCLUSIONS

Bagasse-based energy generation is a powerful example of converting agricultural waste into a valuable resource. It supports sustainable development, reduces environmental impact, and enhances economic growth in rural areas.

With proper investment and technology adoption, sugar mills can become energy producers, contributing significantly to India’s renewable energy sector. The future of bagasse energy looks

1) Energy Yield Metrics (Bagasse-Based Power Generation)

Parameter	Value / Range	Explanation
Energy Output per Tonne of Cane	25–120 kWh/tonne	Depends on boiler pressure & moisture content
Energy Output per Tonne of Bagasse	100–500 kWh/tonne	High-pressure systems generate more power
Calorific Value (Dry Bagasse)	17–19 MJ/kg	Energy available when completely dry
Calorific Value (50% Moisture)	7–8 MJ/kg	Actual usable energy in normal operations
Moisture Impact	Every 5% ↓ moisture → +0.8–1 MJ/kg	Higher efficiency when moisture is lower
Boiler Pressure	20–30 bar (old) / 60–100+ bar (modern)	High pressure = 2–3× more electricity
Steam to Power Ratio	4.0–5.0 kg/kWh	Steam required to produce 1 kWh electricity

Overall Thermal Efficiency	22–32%	Efficiency of bagasse-based cogeneration
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These energy yield metrics show that the electricity produced from bagasse depends on factors such as calorific value, moisture content, boiler pressure, and turbine efficiency. Modern high-pressure cogeneration systems significantly increase energy output compared to traditional low-pressure systems. Reducing moisture content also improves energy yield and overall thermal performance.

TABLE 2: COST COMPARISON

2) **Cost Comparison for Bagasse-Based Cogeneration Systems**

Cost Component	Low-Pressure System	High-Pressure System	Remarks
CAPEX (₹ crore/MW)	2.5–3.2 crore/MW	4.9–5.6 crore/MW	High-pressure = higher investment
OPEX (Annual)	Low	Moderate	Due to advanced components
Electricity Output	25–40 kWh/tonne cane	100–120 kWh/tonne cane	3× higher

Boiler Pressure	20–30 bar	60–100+ bar	Higher efficiency
Export Capability	Very low	High (surplus power)	Revenue opportunity
Payback Period	Long (10+ years)	Medium (6–9 years)	Better returns
IRR (Profitability)	6–8%	12–18%	High pressure = better ROI
Maintenance	Less complex	More technical	Requires skilled staff

This table compares the financial and technical differences between low-pressure and high-pressure cogeneration systems. While low-pressure systems cost less initially, they generate very little surplus electricity and offer limited profitability. High-pressure systems require higher investment but provide significantly greater revenue, faster payback periods, and higher efficiency. Therefore, they are the preferred choice for modern sugar mills in India.

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