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Analysis of Raw Material Potential Based on Leading Commodities for Sustainable Industrial Development in East Java

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Abstract: This study evaluates the potential of molasses (sugarcane molasses) as the main feedstock for bioethanol production with a capacity of 100 kiloliters per day at PT Enaro Mojokerto. Assuming a fermentation efficiency of 90% and a theoretical sugar-to-ethanol conversion ratio of 0.511 kg ethanol per kg sugar, the required sugar is approximately 171.559 kg/day, corresponding to 343 tons of molasses (with 50% sugar content) to produce 100 KL of ethanol per day. Literature review and secondary data collection were conducted to evaluate three main criteria: feedstock availability, supply continuity, and fermentable sugar content. The analysis results indicate that East Java has a molasses production potential of 660,000 tons/year from 15 active sugar mills, with the highest concentration in Malang, Kediri, and Mojokerto regencies. This study concludes that the development of the molasses-based bioethanol industry in Mojokerto is technically and economically feasible with integrated supply chain management support.

Keywords: Bioethanol; East Java; Fermentation; Molasses; Renewable energy sugarcane;

Introduction

Bioethanol is a bio-fuel produced through the fermentation process of sugar or starch from biomass sources. The use of bioethanol as an alternative fuel supports green energy policies and carbon emission reduction, which is a global commitment to addressing climate change. As a member of the Paris Agreement, Indonesia targets a reduction in greenhouse gas emissions of 29% through independent efforts and up to 41% with international support by 2030 (Ministry of Energy and Mineral Resources, 2021). One of the key strategies in achieving this target is the development of renewable energy, including bioethanol as a substitute for fossil fuels.

Indonesia has great potential in bioethanol production given the abundant availability of biomass feedstock, particularly from the agricultural and agroindustry sectors. Molasses or sugarcane molasses is a potential primary feedstock because it is a by-product of the sugar industry that still contains a high fermentable sugar content reaching 45–56% (Paturau, 1989; Chandel et al., 2012; Wirawan et al., 2025; Isteriana et al., 2021; Kumarlea et al., 2020; Wijaya & Kurniawan, 2023). As a country with significant sugarcane production, Indonesia produces approximately 2.2 million tons of molasses per year from 62 sugar mills scattered across various regions, primarily on Java Island (Directorate General of Plantations, 2023; Dewi & Rasmiyana, 2025). However, the utilization of molasses for bioethanol is still limited, with most being allocated to the animal feed industry, monosodium glutamate (MSG), and yeast industries.

The Indonesian government's policy through the Mandatory Biodiesel and Bioethanol Program (B30 and E10) encourages the development of the domestic bioethanol industry. The 10% ethanol blending program with gasoline (E10) is estimated to require bioethanol supply reaching 3.6 million kiloliters per year (Ministry of ESDM, 2022; Singhania et al., 2012). This large

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demand opens investment opportunities for molasses-based bioethanol industry, especially in sugar production center regions such as East Java, which has adequate sugar mill infrastructure.

East Java is the largest sugarcane-producing province in Indonesia with an area reaching 240.000 hectares and sugarcane production of approximately 12 million tons per year (East Java Provincial Plantation Service, 2023; Pereira et al., 2015). Mojokerto Regency, as one of the sugarcane production centers in East Java, has several actively operating sugar mills such as PG Gempolkrep and PG Modjokerto. Geographic proximity to molasses feedstock sources is a strategic advantage for bioethanol industry development in this region, considering that feedstock transportation costs are a significant component in the production cost structure.

This research is focused on evaluating the potential of molasses as feedstock for bioethanol production with a capacity of 100 kiloliters per day at PT Enaro in Mojokerto Regency. The production capacity of 100 KL/day was selected based on considerations of economic scale and the availability of molasses supply from sugar mills around the location. This study includes an evaluation of three main aspects: molasses feedstock availability, year-round supply continuity, and fermentable sugar content affecting production efficiency. By understanding the potential and challenges of utilizing molasses for bioethanol, this research is expected to provide strategic recommendations for sustainable bioethanol industry development in Indonesia, while supporting the achievement of renewable energy mix targets and national carbon emission reduction.

Method

The method used in this research is an objective narrative literature review, which serves as a reference for conducting literature studies. The stages in this research include information and literature collection, information analysis, and review writing. The information and literature used are aligned with the topic or writing variables. The process of conducting a literature review is that the information and literature used are aligned with the topics discussed, which include Indonesia's commitment to reducing emissions, the use of renewable energy sources (RES), sugarcane molasses, bioethanol, sugar mill waste, and energy mix targets and realization.

The initial stage of research involves collecting information and literature from various sources related to the research topic. These sources include official state documents, government reports, and scientific articles indexed in Scopus and Web of Science (Q2 and Q3), and relevant publications, with a focus on aspects such as energy policy, emission reduction commitments, the use of renewable energy sources (RES), sugarcane molasses, bioethanol, sugar mill waste, and energy mix targets and realization.

After data collection, information analysis was conducted by identifying and evaluating patterns, trends, and important findings from various sources. The search for national and international journals was conducted from May to October 2025 using Google Scholar, Scopus, and Web of Science databases. Inclusion criteria include: Q2 and Q3 indexed journal articles, publications within the year range of 2010–2025, relevance to molasses and bioethanol topics, and clear and validated methodology. This research emphasizes the selection of relevant and credible information and comparison among sources to obtain a comprehensive understanding.

The next stage involves writing an objective literature review. In this process, comparisons are made with previous research reference journals by adjusting the research results of those journals to the conceptual framework in this research, which is to analyze the factors of feedstock supply, molasses price, and molasses storage location.

Feedstock Requirement Calculation

The main analysis steps include: (a) Target ethanol volume = 100.000 L/day. (b) Ethanol mass = 100.000 L × 0.789 kg/L = 78.900 kg/day. (c) Theoretical sugar → ethanol ratio = 0.511 kg ethanol/kg sugar. (d) Fermentation efficiency = 90% → effective ratio = 0.4599 kg ethanol/kg sugar. (f) Sugar requirement = 78.900 kg ÷ 0.4599 = 171.559 kg/day. (g) With 50% molasses sugar content, molasses requirement = 171.559 ÷ 0.50 = 343 tons/day. (h) Annual requirement = 343 tons/day × 365 days = 125.195 tons/year.

Regional Availability Analysis

Molasses potential mapping was conducted by identifying: (a) the production capacity of each sugar mill, (b) geographic distance from the PT Enaro location, (c) milling season and operational period, (d) molasses quality (sugar content, impurities), and (e) transportation and storage infrastructure.

The discussion in this research includes an in-depth analysis of current energy use conditions in Indonesia, the balance between production and feedstock availability, progress toward established targets, and optimization of sufficient feedstock availability in achieving production targets each year. Through this scientific approach, this research is expected to make significant contributions to understanding and solving renewable energy problems in Indonesia.

Results and Discussion

Local Molasses Characteristics

Molasses from East Java sugar mills contains 45-56% total sugar (sucrose 30-40%, glucose 5-10%, fructose 5-10%), suitable for bioethanol fermentation (Paturau, 1989; Zabed et al., 2014). Indonesian molasses averages 48% fermentable sugar (Aprinada et al., 2019; Arianto et al., 2024), with composition influenced by sugarcane varieties and extraction processes (Santos et al., 2019; Balat, 2011; Gnansounou & Dauriat, 2010).

Viscosity ranges 5.000-10.000 cP at 25°C, requiring heating to 40-50°C for easier handling and mixing (Bai et al., 2008). Heat treatment also inactivates contaminant microorganisms (Olbrich, 2006; Rifa'i et al., 2022). Molasses contains 8-12% ash, 2-3% protein, with minerals serving as yeast nutrients. SO_2 content (200-400 ppm) remains within fermentation tolerance (<500 ppm) (Zabed et al., 2014). Metal ions affect fermentation kinetics; optimal concentrations enhance productivity while excess inhibits growth (Walker & Stewart, 2016; Nugroho et al., 2022).

Bioethanol Yield Potential

Using Gay-Lussac theoretical conversion (0.511 kg ethanol/kg sugar) with 90% fermentation efficiency:
1 ton molasses (50% sugar) = 500 kg fermentable sugar
Ethanol produced = 500 × 0.4599 = 229.95 kg = 290-295 L/ton molasses.

This aligns with Raharja et al. (2019) reporting 280-300 L/ton from Indonesian molasses. Yield variation depends on sugar content, yeast type, fermentation conditions, and distillation efficiency. Indonesian molasses yields are competitive with Brazil and Thailand (Aditiya et al., 2016; Sunandes et al., 2025).

East Java Molasses Production Potential

East Java's 15 sugar mills process 44.000 tons sugarcane/day, producing 2.200 tons molasses/day. Annual production: 330.000 tons (150-day milling season), yielding 95.7 million liters bioethanol/year.

Production Scenarios for PT Enaro Mojokerto

Four nearest sugar mills can supply 86.250 tons/year. (a) PG Gempolkrep (15 km): 18.750 tons/year. (b) PG Modjokerto (20 km): 22.500 tons/year. (c) PG Tjoekir (35 km): 21.000 tons/year. (d) PG Krebet Baru (85 km): 24.000 tons/year.

Supply Continuity Analysis

Supply Gap: PT Enaro requires 125.195 tons/year for 100 KL/day production, creating a 38.945-ton deficit (31%).
Mitigation Strategy:

Long-term contracts with 4-5 mills following Sorda et al. (2010) supply chain model 10.000-15.000 ton storage tanks for 29-44 days buffer (Cardona & Sánchez, 2007).
Diversification: Central Java mills, imported molasses, trader partnerships
Quality control: minimum 45% sugar, max 500 ppm SO_2, pH 5.0-6.5

Economic Analysis

Cost Structure (Rp 1.350.000/ton molasses):
Daily production cost: Rp 613 million (feedstock + utilities).
Daily revenue: Rp 1,100 million (100 KL @ Rp 11.000/L).
Gross margin: 44.3% (Rp 177.7 billion/year).
Economic feasibility aligns with Nguyen & Gheewala (2008) showing 5-7 year payback for >50 KL/day plants.

Environmental Sustainability

GHG reduction: 73.000 tons CO_2/year (50-60% vs gasoline).
Life cycle emissions: 30-40 gCO_2eq/MJ vs 85 for gasoline (Seabra et al., 2011).
Waste valorization: vinasse to biogas/fertilizer, stillage to animal feed (Wiloso et al., 2016).
Water consumption: 10-15 L/L ethanol, reducible 40% via recycling (Chandra et al., 2012).

Challenges and Risk Mitigation

Key Risks:
Limited milling season: storage investment, supplier diversification.
Price fluctuation: indexed contracts, hedging, vertical integration.
Market competition (feed 40%, MSG 25%, yeast 20%): strategic cooperation, offtake agreements.
Quality variability: strict QC, multi-source blending.
Policy uncertainty: market diversification, export options.
Success depends on stable government policy and incentives (Leal et al., 2013).

Integrated Biorefinery Potential

Integrated model increases revenue 15-25% (Dias et al., 2011) through: (a) Co-products: liquid CO_2, biogas, organic fertilizer, spent yeast. (b) Circular economy integration with sugar mills. (c) Project IRR improvement of 5-8% vs stand-alone production (Bonomi et al., 2016).

Conclusion

Based on the comprehensive analysis results, it can be concluded that: (1) Feedstock Potential: East Java has molasses production potential reaching 330,000 tons/year from 15 active sugar mills, with the highest concentration in Malang, Kediri, and Mojokerto regencies. This potential can support 262 units of 100 KL/day capacity bioethanol plants if operating year-round. (2) Requirements for PT Enaro Mojokerto: To achieve 100 KL bioethanol/day production, 343 tons molasses/day or 125,195 tons/year is required. Four nearest sugar mills (PG Gempolkrep, PG Modjokerto, PG Tjoekir, and PG Krebet Baru) can provide 86,250 tons/year during the milling season, with a deficit of 38,945 tons/year that needs to be fulfilled from other sources. (3) Local Molasses Characteristics: Molasses from East Java sugar mills has a fermentable sugar content of 45–56% with an average of 48%, producing a yield of 290–295 liters bioethanol per ton molasses at 90% fermentation efficiency. (4) Economic Feasibility: With a gross margin of 44.3% and projected annual revenue of Rp 401.5 billion, the 100 KL/day bioethanol project in Mojokerto shows good economic feasibility, with a potential payback period of 5–7 years. (5) Sustainability Strategy: Year-round production continuity requires long-term contracts with 4–5 sugar mills, storage facilities of 10,000–15,000 tons, regional and import supply source diversification, a strict quality control system, and biorefinery concept integration for value optimization. (6) Environmental Benefits: Production of 100 KL bioethanol/day can reduce GHG emissions by up to 73,000 tons CO_2eq/year, equivalent to a 50–60% reduction compared to fossil gasoline use, while supporting Indonesia's NDC targets. (7) Policy Recommendations: Consistent policy support is needed in the form of fiscal incentives for the bioethanol industry, bioethanol base price guarantees, the enforcement of the E10 blending mandate, facilitation of financing access for storage infrastructure, and regulations supporting biorefinery integration.

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Conceptualization, methodology, formal analysis, investigation, data curation, writing—original draft preparation, visualization, project administration, funding acquisition, K.S.B.; validation, resources, writing—revision and editing, supervision, A.S. and D.N.M. All authors have read and approved the final version of this manuscript.

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