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Development of a Python-Based Decision Support System for Evaluating Biomass Price Feasibility in Co-Firing Applications: Evidence from Riau, Indonesia

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ABSTRACT

The utilization of biomass as a co-firing fuel in coal-fired power plants is a strategic element in Indonesia's energy transition. A key challenge lies in accurately assessing the price feasibility of biomass fuel (B3m) and ensuring policy compliance. This study presents a Python-based Decision Support System (DSS) equipped with a graphical user interface (GUI) to compute and evaluate the Highest Benchmark Price (HPT) of B3m adaptively, including a maximum price coefficient ($k \leq 1.2$).The system was tested using 12 actual proposals from B3m suppliers in Riau Province. Results indicate that 58.3% of offers complied with regulatory thresholds, with wood-based B3m proving generally more competitive than palm-based feedstocks. The system enables automated and transparent price feasibility classification. These findings highlight the potential of localized Python-based computational tools to support economic evaluation of renewable energy deployment.

KEYWORDS: *Decision support system, Python, Biomass, Highest benchmark price (HPT), Co-Firing.*

NOMENCLATURE

HPT	Highest Benchmark Price
B3m	Biomass
GUI	Graphical User Interface
CFPP	Coal-Fired Power Plant
k	Price Correction Coefficient
CV	Calorific Value (in kcal/kg)
Fc	Correction factor for biomass CV relative to coal CV
CIF	Cost, Insurance, and Freight (coal price benchmark)
FoB	Free on Board
ESDM	Ministry of Energy and Mineral Resources
RUPTL	National Electricity Supply Plan

1.0 INTRODUCTION

The global energy transition toward cleaner and more sustainable sources is a critical global priority, and Indonesia has aligned itself with this commitment through national-level policies. One of the government's strategic efforts to reduce dependency on fossil fuels, particularly coal, is the implementation of B3m co-firing in coal-fired power plants (CFPP), where B3m is introduced as a supplementary fuel [1]. In line with this strategy, Indonesia's state electricity company, PLN, has set a target to increase B3m co-firing to 7.7 million tons by 2030 [2]. This initiative is underpinned by the country's significant bio-energy potential, which is estimated at 57 GW. Specifically, the potential from municipal solid waste accounts for approximately 19.32 MW, while agricultural and plantation residues contribute an estimated 120.48 MW [3].

Despite this ambitious goal, one of the key challenges in implementation lies in the absence of a systematic and adaptive mechanism to evaluate the feasibility of B3m fuel prices proposed by local suppliers. The Indonesian B3m Energy Society (MEBI) reported that the disparity between actual market prices—especially for exportable B3m types such as wood pellets and palm kernel shells—and the benchmark price regulated by PLN significantly hampers private sector participation in the co-firing program [4].

Historically, the evaluation of B3m price feasibility referred to the PLN Board of Directors Regulation No. 001.P/DIR/2020, which set the B3m price coefficient (k) at a maximum of 0.85 times the coal CIF price as the basis for calculating the Highest Benchmark Price (HPT) [5]. In response to market dynamics, this benchmark has been revised by the Ministry of Energy and Mineral Resources (ESDM) through Ministerial Regulation No. 12 of 2023, allowing for a more flexible pricing coefficient up to 1.2 times the Free-on-Board (FoB) coal price[6]. This policy shift emphasizes the importance of adaptive computational tools capable of accommodating changing regulatory parameters.

Technically, the HPT calculation requires a multi dimensional assessment based on coal CIF price, calorific value (CV) of B3m, CV of coal, and the regulatory coefficient (k). Thus, an intelligent system is needed to simulate and evaluate pricing scenarios dynamically. Python has proven to be a robust platform for developing data-driven Decision Support Systems, particularly within energy engineering domains [7]. Previous research has demonstrated its capability in energy price forecasting [8], power plant monitoring[9], and optimization-based energy simulations[10]. Decision support systems (DSS) have proven effective in guiding operational decisions in thermal power generation [11].

User-friendly tools that employ graphical user interfaces (GUI) have also been recognized as effective in improving accessibility and accelerating data interpretation in industrial settings [12], [13]. Python's Tkinter framework, in particular, has been used to design GUI-based applications for energy monitoring, enabling real-time data processing and visualization [14].

Given these considerations, this study aims to develop a Python-based Decision Support System (DSS), herein referred to as DSS, integrated with a GUIto calculate and evaluate B3m HPT in real time. The system incorporates rule-based logic and dynamic parameters according to national regulations, enabling users to test the feasibility of B3m price offers adaptively. The model is tested using actual B3m price data collected from various suppliers in Riau Province, providing empirical evidence of the system's practicality in supporting B3m procurement decisions for co-firing in Indonesian CFPP. Despite Python's established use in energy systems [7],[8], 9], [10]. No prior study has developed a GUI-based DSS for Indonesia's dynamic B3m pricing policy with real-world validation.

2.0 METHODS

2.1 Regulatory Framework and Data Inputs

This study adopts a regulation-oriented engineering approach by aligning the DSS with Indonesia's latest national energy policies. The core algorithm for calculating the HPT of biomass fuel is formulated by the Ministry of Energy and Mineral Resources Regulation No. 12/2023, which defines HPT as the product of the average FoB coal price, a government-regulated price coefficient (k), and a calorific correction factor (Fc) [6].

$$HPT = CIF\ Coal\ Price \times k \times Fc \qquad (1)$$

$$Fc = \frac{CV\ Biomass}{CV\ Average\ Coal} \qquad (2)$$

Where:
$CIF\ Coal\ Price$ is average coal price over the last three months, including transportation costs. The k is additional correction factor, with a maximum value of 1.2. Fc is correction factor for biomass calorific value relative to coal calorific value. $CV\ Biomass$ is calorific value of biomass (kcal/kg) $CV\ Average\ Coal$ is average calorific value of coal (kcal/kg)

The price coefficient (k) in this study is capped at a maximum of 1.2, as mandated by Indonesia's national energy policy. This parameter is periodically reviewed and adjusted in alignment with prevailing market dynamics and long-term strategic objectives. The FoB coal price was calculated based on a three-month average market survey conducted in Riau Province, ensuring it reflects actual regional economic conditions

The database includes multiple B3m types classified according to their industry of origin (e.g., palm oil, sugarcane, wood, and others). Table 1 presents the calorific values (in kcal/kg) that serve as standard reference inputs for the automated calculation process within the system. These values are derived from a combination of laboratory test results and publicly available data, such as from PLN (2020), documented [5],[6], and are used as default estimates unless manually adjusted by the user.

Table 1: B3m Types and Calorific Values

Industry	B3m Feedstock	Calorific Value (Kcal/Kg)
Palm Oil	Oil Palm Mesocarp Fiber (OPMF)	4000
	Palm Kernel Shell	4300
	Empty Fruit Bunch (EFB)	3800
	Oil Palm Frond (Frond)	3350
	Oil Palm Trunk (Replanting)	3500
Sugarcane	Bagasse	1850
	Sugarcane Leaf and Top Cane	3000
Coconut	Coconut Fiber	3300
	Coconut Shell	4300
Rubber	Rubber Trunk (Replanting)	4200
Rice	Rice Husk	3350
	Rice Straw	2800
Corn	Corn Cob	3500
	Corn Stalk and Leaf	2500
Wood	Wood Pellet	4300
	Wood Chip	2000
	Sawdust	3000

Additionally, actual bid prices from local B3m suppliers in Riau were collected and utilized as empirical inputs to validate the Python-based DSS for HPT calculation. The incorporation of empirical validation with local data enhances the credibility and practical applicability of the DSS tool, consistent with methodologies in region-specific energy pricing models [15].Riau represents Indonesia's largest palm oil and timber producing region, making it ideal for testing diverse B3m feed stocks [16].

2.2 Algorithm and Computational Logic

The core computational engine is constructed using Python, employing a rule-based algorithmic structure integrating *if-else conditionals*, *looping structures*, and *user-defined functions* to enable dynamic, scenario-based simulations. This design approach is consistent with principles in the development of Python-based energy systems [7] and modular evaluation tools such as DIETERpy [10].

The central function that performs the HPT calculation is shown in Listing 1. The algorithm receives four key parameters: CIF coal price, calorific value of coal, calorific value of B3m, and the coefficient *k*. These variables are dynamically adjustable via the GUI. The following function, shown in Listing 1, implements the official HPT formula

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defined by Ministerial Regulation No. 12/2023, translating it into a modular Python function.

Listing 1: Python function for HPT calculation

```
def hitung_hpt_biomassa(harga_batubara_cif, cv_biomassa,
cv_batubara, k):
    Fc = cv_biomassa / cv_batubara
    return harga_batubara_cif * k * Fc
```

This concise yet powerful function follows the structure prescribed in regulatory documents and has been tested for numerical consistency under multi-scenario simulations. To support flexibility, the system enables users to choose between manual or default values for both the B3m calorific value and the coefficient *k*, using conditional logic implemented via *if–else statements*. This allows the application to adapt dynamically to inputs, instrumental in field scenarios where test results may vary. To enable dynamic user control, the system provides manual input features for both the price coefficient (k) and the calorific value (CV), as illustrated in Listings 2 and 3.

Listing 2: Manual input feature for price coefficient (k)

```
self.var_k_manual = tk.BooleanVar()
self.check_k_manual = ttk.Checkbutton(self.input_frame,
    text="Input Koefisien k Manual",
    variable=self.var_k_manual,
    command=self.toggle_k_input
)
self.entry_k_manual = ttk.Entry(self.input_frame,
state="disabled")
```

Listing 3: Manual input feature for calorific value (CV)

```
self.var_cv_manual = tk.BooleanVar()
self.check_cv_manual = ttk.Checkbutton(frame, text ="Input
Kalori Manual", variable=self.var_cv_manual,
command=self.toggle_cv_input)
self.entry_cv_biomassa = ttk.Entry(frame, state= "disabled")
```

Listing 4: Input Interface Setup (Tkinter GUI Configuration)

```
self.combo_industri = ttk.Combobox(frame_biomassa,
values=list(data_kalori.keys()), state="readonly")
self.combo_bahan = ttk.Combobox(frame_biomassa,
state="readonly")
self.entry_cv_biomassa = ttk.Entry(frame_biomassa,
state="disabled")
self.check_cv_manual = ttk.Checkbutton(...,
command=self.toggle_cv_input)
```

This structure enables scenario-based simulations in, which various B3m types and pricing schemes can be systematically compared. Such configurability is critical for decision-making in policy-driven contexts, where feasibility thresholds depend on regulatory and market-specific conditions. This approach is consistent with techno-economic simulation methodologies applied in recent B3m co-firing studies [17],[18].

2.3 System Architecture and GUI Implementation

To enhance usability, the DSS is developed using Python's Tkinter library, allowing for a lightweight but effective Graphical User Interface [19]. The interface facilitates real-time data entry, visual feedback, and clear output classification for stakeholders. Listing 4 presents the GUI configuration for user input, where Tkinter widgets are used to capture biomass parameters and trigger manual override functionalities for calorific value and price correction coefficients. These widgets represent core user controls, enabling flexibility in scenario testing.

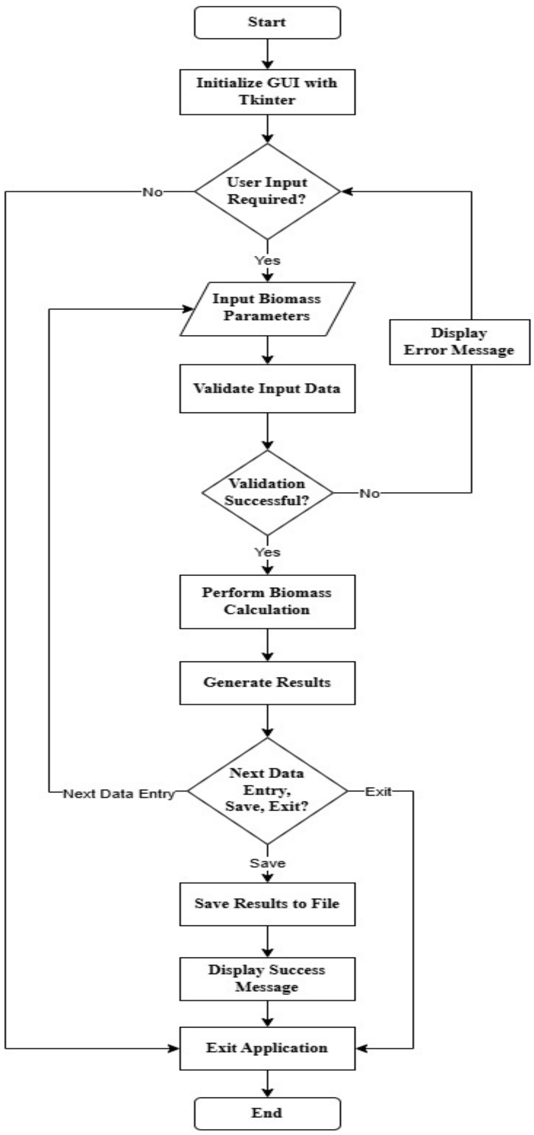

Figure 1: System flowchart of biomass HPT calculation

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This interface is designed to facilitate interactive data inputs, allowing users to select predefined B3m types, manually input specific parameters, and observe calculation results in real time. Furthermore, this DSS functions as a strategic tool with dual utility: it assists B3m-receiving power plants in objectively evaluating bid feasibility, while simultaneously enabling B3m suppliers to formulate price offers by regulatory benchmarks. This dual functionality is critical for enhancing transparency and price negotiation efficiency throughout the B3m supply chain. The entire system architecture is depicted in Figure 1, which outlines the flow from data input to decision output. This structure ensures traceability and transparency, consistent with standards in techno-economic validation of energy software systems [20].

3.0 RESULT AND DISCUSSION

3.1 System Output and Decision Logic Validation

The developed DSS, designed using Python and the Tkinter GUI framework, has demonstrated successful functionality in calculating the HPT of B3m across various test scenarios. The application interface facilitates user interaction through modules for entering coal CIF price, B3m calorific values (manual or default), and offering prices submitted by local B3m suppliers. The system is equipped with conditional logic that allows users to toggle between default regulatory parameters and manually tested values, thereby increasing its adaptability in real-world use cases.

Once the input data is provided, the system executes real-time computations and generates classifications of the price feasibility. The results are clearly labeled as "Compliant" or "Non-Compliant" concerning the regulatory framework outlined in the Ministry of Energy and Mineral Resources Regulation No. 12/2023 and PLN's internal directive [5],[6]. The application also includes functions for scenario resetting, result export to Excel, and automated archiving for traceability.

The computation logic has been internally verified for consistency across all input configurations, ensuring functional alignment with the expected regulatory outcomes. Structure and functional elements of the interface are illustrated in Figure 2, which highlights the modular organization and the interactive design of the system. Subsequently, a populated interface with real input data from the Riau Province is shown in Figure 3, demonstrating the full application workflow and an example classification of a B3m offer as compliant under the computed HPT threshold.

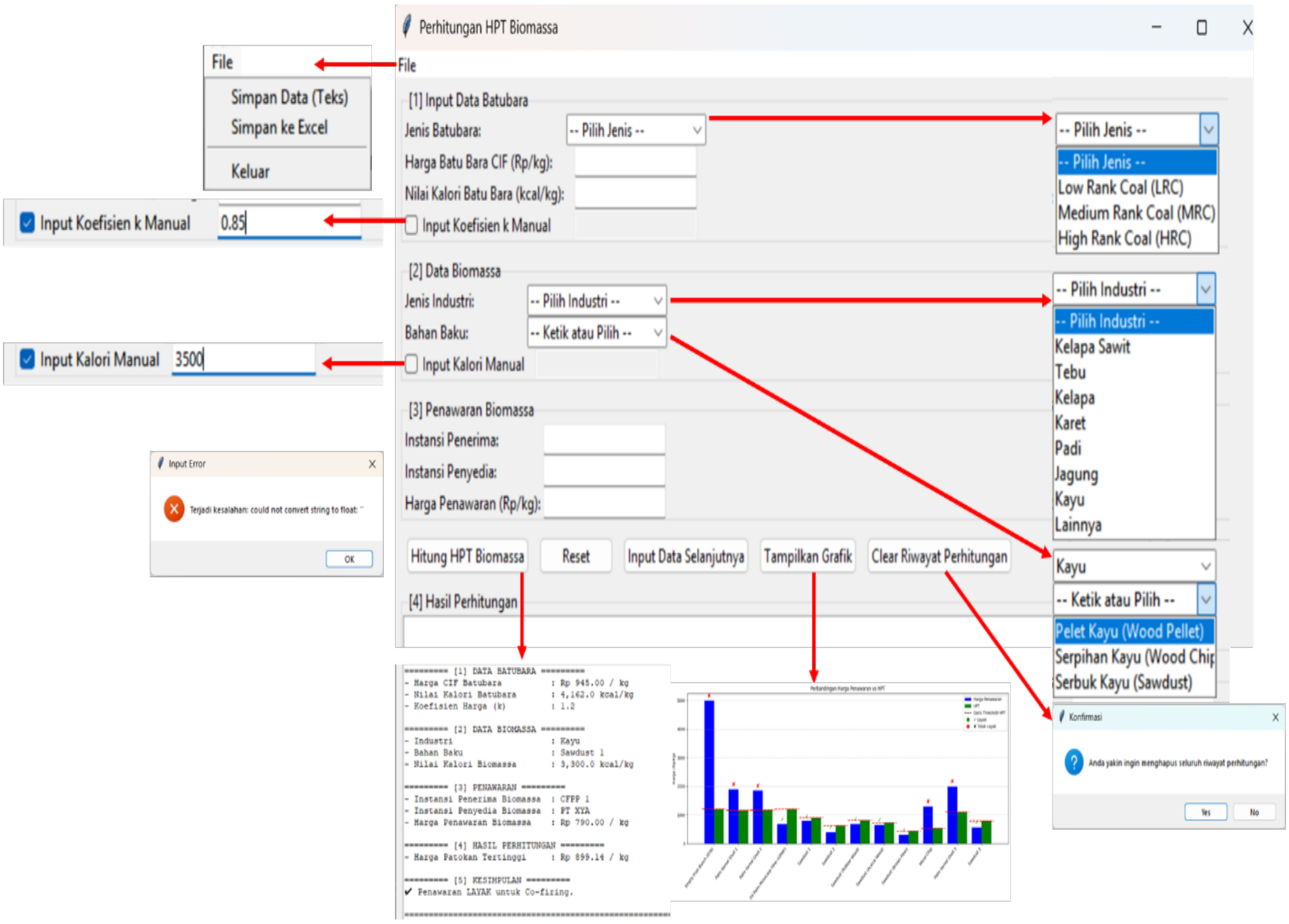

Figure 2: Interface architecture and control elements of the Python-based DSS for evaluating HPT of B3m offers

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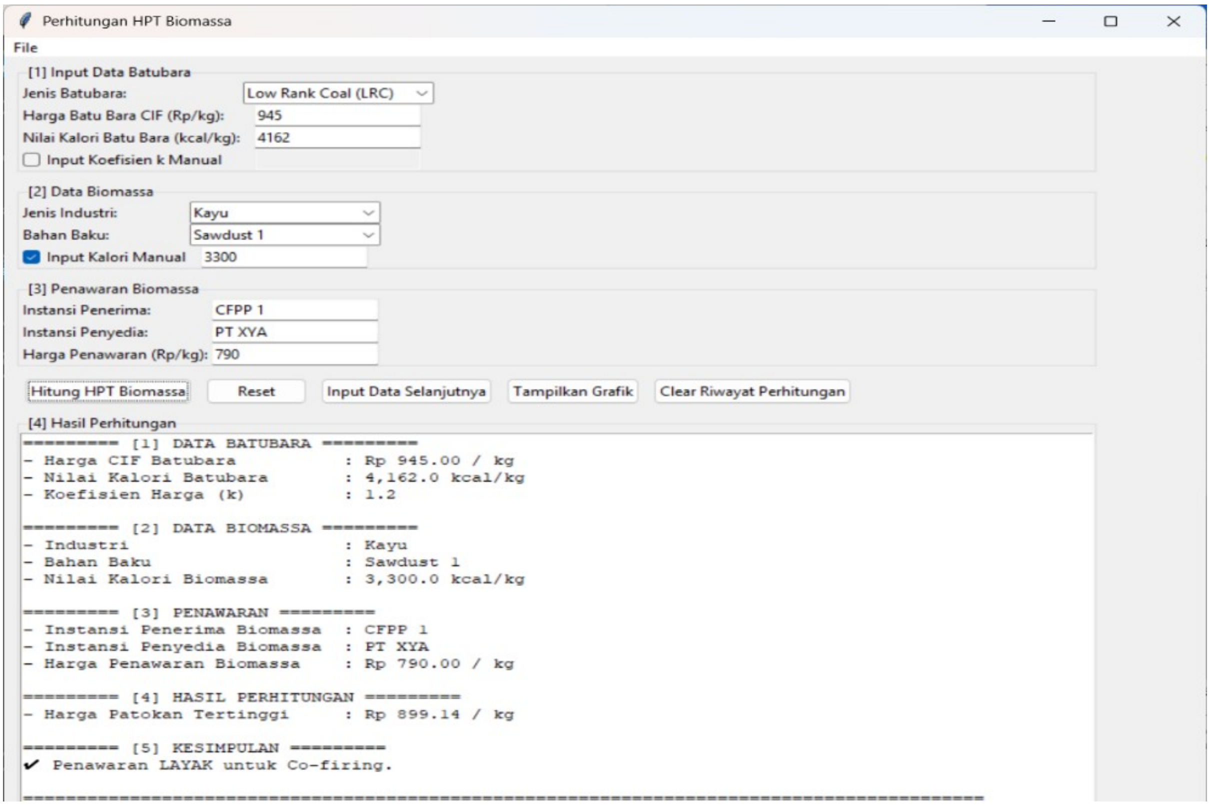

Figure 3: Populated DSS interface using actual B3m offer data from Riau Province

3.2 Empirical Validation Using Market Data in Riau

To validate the system under practical field conditions, twelve B3m price offer records were collected from two CFPP operating in Riau Province. These records were directly sourced from actual B3m tender submissions received by two coal-fired power plants in Riau Province, providing a realistic basis for testing the Python-based DSS. The variation in coal CIF prices—Rp 945/kg for CFPP 1 and Rp 882/kg for CFPP 2—reflects localized procurement strategies and market dynamics, thereby ensuring representativeness in the validation process.

All coal types used in these CFPP fall into the low-rank coal category (LRC), as classified by ISO 11760:2005, which segments coal into low, medium, and high rank based on vitrinite reflectance and maturity indicators[21]. For consistency in the HPT calculation, the calorific values of 4,162 kcal/kg for CFPP 1 and 4,014 kcal/kg for CFPP 2 were determined through laboratory testing of coal samples from each power plant, conducted by ASTM D5865-13 standards.

Of the twelve B3m entries, ten included calorific values obtained through laboratory testing, while the remaining two relied on default values stored within the system database. The calorific value measurements followed the ASTM D5865-13 standard for gross calorific value and were reported on an "As-Received Basis (ARB)" to reflect field-operational conditions [22]. This hybrid validation strategy enabled the comparison of actual test results with default parameters embedded in the application. The observed minimal deviation between lab results and system values confirms the reliability of the internal database. Nevertheless, laboratory testing remains essential for precision, as B3m properties are highly sensitive to factors such as moisture content, particle size, and contamination. The system processed each dataset and classified it as either Compliant or Not Compliant, depending on whether the offered price was below or above the calculated HPT. These results are presented in Table 2.

To illustrate the classification results, Figure 4 compares the offered prices with the system-generated HPT values for each feedstock. Each B3m type is represented on the X-axis, and the corresponding price in Rp/kg is plotted on the Y-axis. Red bars identify offers that exceed the HPT, while others fall within acceptable thresholds. This empirical validation demonstrates that the Python-based DSS successfully distinguishes between offers that comply with government price ceilings and those that do not, based on adaptive regulatory logic. Additionally, a regional pricing trend becomes evident: B3m sourced from the palm oil industry—such as empty fruit bunches and palm kernel shells—typically shows higher prices due to preprocessing, drying requirements, and limited local availability. In contrast, wood-based B3m—particularly sawdust—tends to be more affordable and abundant in Riau due to widespread furniture and plywood industries [23].

These findings are consistent with broader research on the B3m value chain, which identifies moisture variability and fragmented logistics as primary cost drivers for palm-based B3m [24]. Hence, the system not only operates as a compliance filter but also surfaces economic feasibility patterns critical for localized policy interventions.

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Table 2: System output summary based on market offers from Riau CFPP

CIF Coal Price (Rp/Kg)	Coal Calorific Value (Kcal/Kg)	Biomass CFPP	Biomass Calorific Value (Kcal/Kg)	Feedstock Type	Offered Price (Rp/Kg)	HPT (Rp/Kg)	Feasibility
945	4,162	CFPP 1	4,449	Empty Fruit Bunch (EFB)	5,000	1,212.20	Not Feasible
945	4,162		4,264	Palm Kernel Shell 1	1,900	1,161.79	Not Feasible
945	4,162		4,300	Palm Kernel Shell 2	1,850	1,171.60	Not Feasible
945	4,162		4,447	Oil Palm Mesocarp Fiber (OPMF)	678	1,211.65	Feasible
945	4,162		3,300	Sawdust 1	790	899.14	Feasible
945	4,162		2,332	Sawdust 2	400	635.39	Feasible
945	4,162		2,968	Sawdust (Rubber Wood)	680	808.68	Feasible
945	4,162		2,683	Sawdust (Acacia Wood)	650	731.02	Feasible
945	4,162		1,598	Sawdust (Brown Fiber)	300	435.40	Feasible
945	4,162		2,000	Wood Chip	1,300	544.93	Not Feasible
882	4,014	CFPP 2	4,190	Palm Kernel Shell 3	2,000	1,104.81	Not Feasible
882	4,014		3,000	Sawdust 3	570	791.03	Feasible

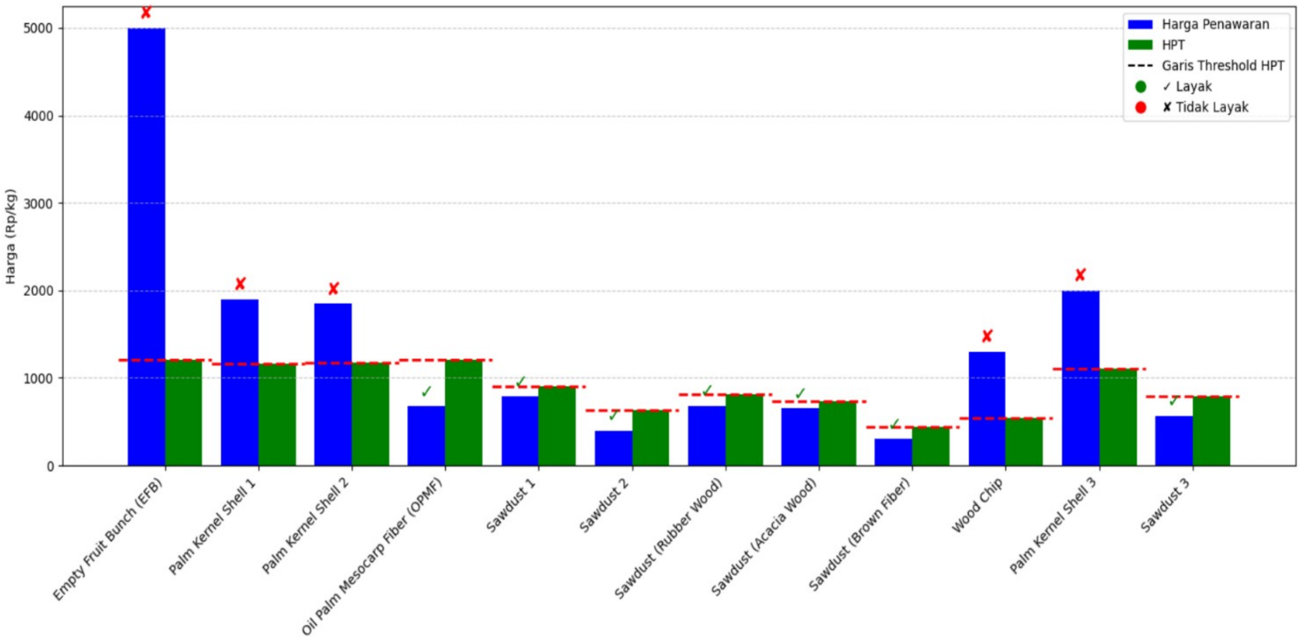

Figure 4: Comparison of biomass offered prices and HPT in Riau

3.3 Regional Insights and Policy-Relevant Interpretation

The regional assessment of B3m feedstock availability in Riau Province reveals a high degree of technical and economic feasibility for sourcing wood-based residues, particularly sawdust, for co-firing applications. Field visits conducted by the authors across Kampar Regency and Pekanbaru City, specifically to artisanal sawmill clusters in Salo and Teratak Buluh, as well as licensed facilities such as PT Rubber Wood Industries and PT Ewan Super Wood, confirmed that sawdust is abundantly available, with daily volumes ranging from 1 to 12 tons per site depending on industrial scale and processing capacity.

At the artisanal level, approximately 50 small-scale sawmills were identified, with each producing 2 to 6 tons of sawdust per day. In contrast, large-scale operations such as PT Rubber Wood Industries and PT Ewan Super Wood yielded between 8 and 12 tons per day. Despite this substantial supply, many artisanal producers offer sawdust at zero cost, requiring buyers to cover only transport expenses, which average around Rp 300/kg. This affordability is partly due to weak demand competition, as sawdust is only marginally utilized by the local wood-panel and fertilizer industries in the Pekanbaru region.

Logistical feasibility is further supported by existing transport infrastructure. Most collection sites are accessible by dump trucks or medium-duty vehicles (e.g., Colt Diesel), with distances to the nearest coal-fired power plants (CFPP) ranging

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from 22 to 85 kilometers. These logistics profiles suggest that locally sourced B3m is not only cost-effective but also practically transportable often over looked criterion in macro-level policy modeling.

A dual compliance landscape was also observed. While registered mills operate under formal legal standards, many artisanal saw-mills function informally and without licensing. This raises critical issues related to procurement traceability and regulatory audit-ability. In response, future iterations of the DSS could incorporate binary legality flags or automated permit-checking modules to help power plant operators distinguish eligible from ineligible suppliers

These field-based insights are consistent with prior findings by Ninomiya et al. [16], who identified Riau Province as possessing surplus sawdust volumes that exceed co-firing demand projections across the ASEAN region. That study also noted structural inefficiencies—including fragmented supplier networks and a dominance of informal actors—which were corroborated by this research's ground observations.

Economically, our findings reinforce those of Reeb et al .[25] and Handaya et al. [26], who reported that palm-based B3m (e.g., empty fruit bunches, palm kernel shells) tends to carry higher processing and logistics costs than wood-based alternatives. The latter offers more stable supply chains and favorable price-performance ratios, making them better suited for decentralized co-firing operations. Triani et al .[27]also highlight the importance of digital tools such as DSS in evaluating procurement feasibility—an objective achieved in this study through adaptive HPT computation and regulatory compliance screening.

To facilitate national roll-out, the DSS can be interfaced with PLN's Integrated Fuel Procurement Dashboard (E-Proc PLN) via a lightweight REST API. Bid data entered through the GUI can be automatically pushed to PLN's centralized platform, enabling near-real-time screening of biomass offers and seamless integration into the utility's contract-management workflow. This architecture would enable PLN and the Ministry of Energy and Mineral Resources to access consolidated analytics for B3m feasibility across regions, thereby linking real-time field inputs with centralized policy oversight and enforcement. By integrating market offers, calorific values, transport estimates, and regulatory constraints, the DSS functions not only as a technical screening tool but also as a policy-aligned decision-making instrument capable of accelerating co-firing adoption under Indonesia's Presidential Regulation No. 112/2022 [28].

4.0 CONCLUSION

This study designed, implemented, and empirically validated a Python-based Decision Support System (DSS)—equipped with a Tkinter graphical interface—to evaluate the price feasibility of biomass fuel (B3m) for co-firing in Indonesian coal-fired power plants. Using twelve market offers from Riau Province and incorporating key regulatory inputs (biomass calorific value, three-month average coal CIF price, and the mandated price coefficient $k \leq 1.2$), the system automatically computes the Highest Benchmark Price (HPT) and classifies each bid as *feasible* or *non-feasible*. Field surveys in Kampar and Pekanbaru confirm that sawdust is both abundant and cost-competitive, reinforcing the DSS finding that wood-based residues outperform palm-based feed stocks on a delivered-cost basis. By operation on the formulae in Ministerial Regulation No.12/2023and PLN Director Regulation No.001.P/DIR/2020,and aligning them with the renewable energy acceleration targets of Presidential Regulation No.112/2022, the DSS bridges technical analytics with national policy mandates. Its intuitive GUI lowers the entry barrier for provincial power plant operators and local biomass suppliers, thereby enhancing transparency and negotiation efficiency. To scale impact beyond this pilot deployment, the DSS can be integrated with PLN's Integrated Fuel Procurement Dashboard (E-Proc PLN) or the forthcoming ESDM Renewable Energy Monitoring Portal via a lightweight REST API. Such coupling would institutionalise standardised, policy-compliant procurement across Indonesia's CFPP fleet and provide regulators with a consolidated, real-time view of regional biomass markets. Several limitations remain. The prototype relies on static transport cost assumptions, lacks automated verification of supplier legality, and is not yet linked to PLN's central data warehouse. Future work will embed dynamic logistics routing, binary legality flags, predictive analytics, and a threshold-line visualisation in the GUI, while porting the architecture to a cloud-based micro-service capable of interfacing directly with PLN and ministry dashboards. Overall, the proposed DSS constitutes a replicable, policy-aligned, and technologically streamlined solution that can accelerate Indonesia's transition toward sustainable power generation by ensuring that biomass co-firing procurement is both economically sound and regulatory compliant.

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