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Process Improvement of Rotary Kiln (RK) Technology with Electric ARC Furnace (EAF) at PT Sebuku Iron Lateritic Ores Using a Technometric Approach

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Abstract.
This study aims to assess the contribution of RK and EAF technologies using a technometric approach, focusing on four technological components: Technoware, Humanware, Inforware, and Orgaware (THIO). Furthermore, the study analyzes the economic feasibility of both systems using financial indicators and sensitivity risk analysis. The methodology includes calculating the Technology Contribution Coefficient (TCC) for each technology based on the degree of sophistication, state of the art, and intensity of use. Additionally, the economic analysis employs indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (B/C Ratio), and Payback Period, along with sensitivity analysis on cost and interest rate variables. The results show that both technologies fall into the semi-modern category, with TCC values of 0.7588 for RK and 0.7563 for EAF. However, Humanware in RK and Inforware in EAF are identified as the weakest contributing components, highlighting priority areas for improvement. From an economic perspective, EAF outperforms RK across all financial indicators under both optimistic and pessimistic scenarios. These findings lead to a recommendation for a gradual transformation from RK to EAF, emphasizing workforce development, information system digitization, and technological management enhancement. The primary output of this research is the development of a technology contribution assessment model based on technometric analysis, integrated with economic feasibility evaluation, providing a strategic foundation for more precise technology and investment decision-making in the mineral processing industry.

Keywords: Rotary Kiln, Electric Arc Furnace, Technometrics, Technology Contribution, Economic Feasibility, Steel Industry

INTRODUCTION

Infrastructure is one of the main drivers of Indonesia's economic growth, playing a vital role in improving quality of life and national welfare indicators (Khoirunurrofik & Anas, 2023). Steel, made from iron ore, is one of the most common materials in the world. According to the World Steel Association (2024), global steel production in 2023 reached 1.892 billion tons, with China as the largest producer, recording 1,019.1 million tons or 53.9% of total output. Other countries in the top ten steel producers include

India, Japan, the United States, Russia, South Korea, Germany, Turkey, Brazil, Iran, Italy, and Vietnam.

From 2000 to 2023, China's steel production demonstrated significant growth, marking the beginning of the *"second stage steel age."* In Indonesia, the steel industry is projected to grow by 4–5 million tons with the operation of integrated steel plants. The national steel industry has strong growth potential and is expected to record significant expansion in the coming decades. Key drivers include supportive government policies, energy efficiency, and technological advancements in domestic steel plants (Ministry of Energy and Mineral Resources & Directorate General of Mineral and Coal, 2021).

However, domestic steel demand still heavily relies on imported raw materials and finished products. Around 55% of the national steel demand can be supplied by local manufacturers, while the remaining 45% is imported (Ministry of Energy and Mineral Resources & Directorate General of Mineral and Coal, 2021). The limited capacity of smelters to process iron ore remains a major obstacle, even though the government has established policies to enhance domestic raw material processing.

Indonesia possesses approximately 2.9 billion tons of iron ore reserves, located mainly in Kalimantan and Sulawesi. These resources consist of primary iron ore (29%), laterite (41%), and iron sand (30%). In terms of reserves, laterite dominates with 40%, followed by primary ore (35%) and iron sand (25%) (Ministry of Energy and Mineral Resources & Directorate General of Mineral and Coal, 2021). This significant potential presents a major opportunity for developing a more self-reliant national steel industry.

In steel production, there are two main methods of processing iron ore concentrate (Sohn & Roy, 2022a). The first is direct reduction in a *rotary kiln* followed by melting in an *Electric Arc Furnace (EAF)*, as practiced by New Zealand Steel and Highveld Steel & Vanadium Corp Ltd in South Africa. The second is blast furnace smelting, used by Panzhihua Iron and Steel in China and NTMK in Russia. These technologies produce sponge iron, pig iron, and steel with high energy efficiency.

Indonesian regulations, such as Law No. 11 of 1967 and Law No. 4 of 2009 on Mineral and Coal Mining, require Mining Business License (IUP) holders to increase the value-added of mineral resources domestically. One company implementing this mandate is PT Sebuku Iron Lateritic Ores in Sebuku Island, South Kalimantan, which has substantial laterite iron ore deposits and plans to build a smelter with a pig iron production capacity of 260,000 tons/year.

PT Sebuku Iron Lateritic Ores is currently focusing on optimizing iron ore processing technology through the integration of *Rotary Kiln (RK)* and *Electric Arc Furnace (EAF)*. The company conducts technology contribution assessments using the technometric approach (*Technoware, Humanware, Inforware, Orgaware*) and economic feasibility evaluations through methods such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PbP), and Benefit-Cost Ratio (B/C) to ensure investment effectiveness.

Previous studies have investigated the steel production industry and its technological and economic challenges. For instance, Sohn and Roy (2022b) analyzed global iron ore processing technologies and highlighted the efficiency of integrating direct reduction and *Electric Arc Furnace (EAF)* methods, showing that countries such as New Zealand and South Africa have successfully implemented these technologies to optimize energy consumption and output quality. Similarly, Khoirunurrofik and Anas (2023) examined the relationship between infrastructure development and steel demand in Indonesia, emphasizing the reliance on imported raw materials and the resulting vulnerability of domestic steel supply chains. While both studies provide valuable insights into technological efficiency and demand dynamics, they have limitations in addressing the strategic decision-making process for domestic companies aiming to optimize local mineral resource utilization.

This study aims to provide strategic recommendations for PT Sebuku Iron Lateritic Ores' management in selecting the best technology investments to enhance productivity and operational efficiency. By optimally utilizing domestic mineral resources, this strategy is expected to support national steel industry self-sufficiency, improve competitiveness in the global market, and promote sustainable steel industry development. By doing so, this study contributes not only to the optimization of domestic iron ore processing technologies but also to national policy goals on resource-based industrial self-sufficiency, enhancing the competitiveness of Indonesia's steel industry in global markets. The results are expected to guide management decisions in technology investments, improve operational productivity, and promote sustainable development in the domestic steel sector.

MATERIALS AND METHOD

This research focuses on the assessment of technological contributions, particularly in two existing systems, namely the Rotary Kiln and Electric Arc Furnace, combined for processing raw material iron ore to produce pig iron using technometric and economic feasibility methods. The study is conducted at PT Sebuku Iron Lateritic Ores, which, in 2024, initiated a review and application of the combination of these two existing technologies.

The identification phase includes several activities, such as recognizing problems, gathering information through literature review and field observations. This phase proceeds with the assessment, evaluation, and review of the technical aspects of the iron ore processing, based on both the literature and direct field observations. The first step is identifying the issues related to the study object, PT Sebuku Iron Lateritic Ores, by understanding the background and analyzing the existing gaps in the systems or processes. Literature studies aim to acquire a thorough understanding of the concepts and methods required to solve the identified problems and support the research objectives. Field studies, conducted through direct observations, provide real, tangible information that is crucial for understanding the characteristics of the study object.

The data collection phase begins by formulating and creating a scoring form for evaluating the four technology components in the technometric method: Technoware, Humanware, Inforware, and Orgaware (THIO). These components focus on the two existing technologies—Rotary Kiln (RK) and Electric Arc Furnace (EAF)—to produce pig iron at PT Sebuku Iron Lateritic Ores. The criteria for these components are used in a Focus Group Discussion (FGD) to align perceptions on the assessment of the study object. The primary data is collected through field observations and secondary data from books and journals, supporting the formulation of the existing technology assessment. This data includes both direct observations and secondary data on the technology and company structure.

In the data collection process, several techniques are applied, including closed-ended questionnaires, in-depth interviews, and direct observation. Questionnaires are used to gather relevant internal company data. In-depth interviews provide a more comprehensive understanding and serve as references for formulating research strategies. Direct observation ensures that the findings reflect real, on-the-ground conditions. Respondents for the questionnaires and interviews include 10 individuals from various levels, ranging from supervisors to top management at PT Sebuku Iron Lateritic Ores, specifically in the Metallurgy, Fabrication, and Engineering departments. Data obtained during direct observation includes the company's history, vision, mission, organizational structure, product types, machinery used, employee involvement, and more. The data will be processed using technometric and economic feasibility models, including NPV (Net Present Value), IRR (Internal Rate of Return), PbP (Payback Period), and B/C Ratio (Benefit-Cost Ratio).

Technometrics

The first step is to calculate the SOTA value of each component of *Technoware*, *Humanware*, *Inforware*, and *Orgaware* (THIO) technology. This calculation of value involves the value and weight of each component of the technology. Therefore, it is necessary to calculate the weight of each criterion on each component using *the Analytical Network Process (ANP)*. Then the data processing is carried out according to **equations 2.5 – 2.8**.

The State of The Art in each technometric component can be systematically modeled with the following explanation:

1) *State of The Art* for item I *technoware*:

$$ST_i = \frac{1}{10}\left[\sum_K \frac{Tik}{kt}\right] \text{ in which k = 1,2, ..., } k_t \quad (2.5)$$

2) *State of The Art* For item J from *Humanware*:

$$SH_j = \frac{1}{10}\left[\sum_t \frac{Hjl}{lh}\right] \text{ which l = 1,2, ..., } l_h \quad (2.6)$$

3) *State of The Art* for item m from *infoware*:

$$SI = \frac{1}{10}\left[\sum_m \frac{fm}{mf}\right] \text{ in which m = 1,2, ..., } m_f \quad (2.7)$$

4) *State of The Art* for item n from *infoware*:

$$SO = \frac{1}{10}\left[\sum_n \frac{on}{no}\right] \text{ in which n = 1,2, ..., } n_o \quad (2.8)$$

Next, the contribution of each component of THIO technology is determined. This calculation involves the *Degree of Sophisticated* value (level of technological sophistication) and the SOTA value of each technology component. The calculation was carried out using **equations 2.9 – 2.12**. Each component of technology has a different intensity of contribution to the company.

1) $$Ti = \frac{1}{9}*\left[L_{Ti} + S_{Ti}\left(U_{Ti} - L_{Ti}\right)\right] \quad (2.9)$$

2) $$H_j = \frac{1}{9}*\left[L_{Hj} + S_{Hj}\left(U_{Hj} - L_{Hj}\right)\right] \quad (2.10)$$

3) $$I = \frac{1}{9}*\left[L_I + S_I\left(U_I - L_I\right)\right] \quad (2.11)$$

$$O = \frac{1}{9}*\left[L_o + S_o\left(U_o - L_o\right)\right] \quad (2.12)$$

So that an estimate of each technology component is carried out using *ANP*. The activity of estimating the intensity of the contribution of this technology component can be completed using *the Super Determination* program. The last step is to calculate *the Technology Contribution Coefficient* (TCC) which describes the overall state of the company's technology. This calculation involves the value of the contribution and the intensity of the contribution of all components of the technology. The calculation is carried out using **equation 2.1**.

Economic Feasibility

After calculating the TCC value for each component of *Technoware*, *Humanware*, *Inforware*, and *Orgaware* (THIO) technology on the observation object, then an economic feasibility calculation is carried out to determine the best investment in iron ore processing technology for PT Sebuku Iron Lateritic Ores, when *adjusment* and a combination of 2 technologies, namely *Rotary Kiln* and electric arc furnace to create *pig iron*. Based on the economic feasibility component data obtained, the calculation was made using the following methods: *Net Present Value* (NPV) in accordance with **equation 2.13**, *Internal Rate of Return* (IRR) **equation 2.14**, *Payback Period* (PbP) **equation 2.15**, and *Benefit Cost Ratio* (*B/C Ratio*) **equation 2.16**.

$$NPV = \sum_{t}^{n} = 1 \frac{CFt}{\left(1+K\right)^{t}} - Io \quad (2.13)$$

Information:
CFt = Cash flow per annum in period t
Io = Initial investment in year 0
K = Suku bunga

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_1} x\left(i_2 - i_1\right) \quad (2.14)$$

Information:
i1 = The *discount rate* generated by NPV_1
i2 = The discount *rate* number created by NPV_2

$$PbP = \frac{Net - Investment}{Rata - rata - Cash - Inflow} \quad (2.15)$$

$$B / C = \frac{NPV^{+}}{NPV^{-}} \quad (2.16)$$

Then after obtaining the results of the calculation of economic feasibility using the NPV, IRR, PbP, and *B/C Ratio* methods , it is expected to be able to project whether *the adjusation* and combination of the 2 technologies is financially profitable or even detrimental, besides that it is also a consequence for the management of PT Sebuku Iron Lateritic Ores in choosing a technology investment in increasing production capacity.

Analysis and Interpretation Stage

At this stage, data analysis and interpretation are carried out based on the results of data processing. There are several perspectives to conduct the analysis, namely from the formulation of technometric models, the calculation of the contribution of technology components, the use of *the Analytical Network Process* (ANP), and the calculation of the economic feasibility of an investment in technology improvement in the company.

Data interpretation is carried out at each important point based on the results of the analysis of the literature review that has been carried out.

Managerial Implications

Managerial implications are logical consequences of the results of the analysis and interpretation of study data that have been carried out on the object of study. These implications are not something that is formulated separately, but rather arise naturally as an impact of the study's findings on policy, strategy, or managerial operational aspects. In the context of this study, the implications provide an overview of the direction of managerial actions that can be taken by companies, especially in designing technology development and transformation programs. By considering the research findings, the company is expected to be able to implement measures that are more targeted, efficient, and oriented towards long-term competitive advantage.

Stages of Conclusion and Advice

This stage is the concluding part of a series of research processes. Based on all the processes that have been gone through before, a conclusion is drawn that summarizes the answer to the problem formulation. In addition, constructive suggestions were also presented that can be used as input in discussions and considerations for further research.

RESULTS AND DISCUSSION

Performance Indicators of PT Sebuku Iron Lateritic Ores

Table 1. Performance Criteria Indicators of Iron Ore Refining Technology

Indicator / **Iron Ore Refining Technology**	***Rotary Kiln* (RK)**	***Electric Arc Furnace* (EAF)**
Types of Technology	**Direct Reduction**	**Melting with Electric Arc**
Production Stage	*(Sponge Iron)*	*(Pig Iron)*
Operating Temperature (°C)	1.050–1.100	>1.600
Energy Consumption (GJ/ton)	12–14	5–6
Output Kandungan Fe (%)	75–84	93,99
Main Fuel	Coal	Electrical Energy
CO_2 emissions (kg CO_2/ton)	±1.800–2.200	±400–600
By-Products	Fly Ash, Tailing	Battle
Process Efficiency	Keep	Tall
Potential Use of Waste Energy	Low	Medium-High

Indicator / **Iron Ore Refining Technology**	***Rotary Kiln* (RK)**	***Electric Arc Furnace* (EAF)**
Types of Technology	**Direct Reduction**	**Melting with Electric Arc**
Warna Reduksi / Colour Removal (%)	47–50%	94–96%
Supporting Technology Needs	*RK, Ball Mill*	Arc Regulator
Number of Days of Operation	98	98

Assessment of Iron Ore Processing Technology with Technometric Method
Assessment Degree of Sophistication

Degree of Sophisticated Technoware

Rotary Kiln

The technoware components in the Rotary Kiln process consist of Rotary Dryer, Rotary Kiln, Ball Mill, Cooling System, Purification System, Automatic Control System, Gas Emission Control System and Consumption Efficiency. Table 2 shows the results of data analysis related to weighting on each component obtained using the ANP method.

Table 2. Weighting of Technoware Components - Rotary Kiln

Component	Weight	Priority
Purification System (SPM)	0.1430	1
Rotary Kiln (RK)	0.1408	2
Energy Consumption Efficiency (EKE)	0.1352	3
Gas Emission Control System (GEC)	0.1166	4
Rotary Dryer (RD)	0.1183	5
Cooling System (SP)	0.1157	6
Automatic Control System (SKO)	0.1151	7
Ball Mill (BM)	0.1152	8

Electric Arc Furnace

The technoware components in the Electric Arc Furnace process consist of Rotary Kiln, Electric Arc Furnace, Cooling System, Purification System, Electrode System, Transformer System, Gas Cleaning System and Consumption Efficiency. Table 3 shows the results of data analysis related to weighting on each component obtained using the ANP method.

Table 3. Weighting of technoware Components - Electric Arc Furnace

Component	Weight	Priority
Electric Arc Furnace (EAF)	0.1425	1

Component	Weight	Priority
Purification System (SPM)	0.1320	2
Energy Consumption Efficiency (EKE)	0.1295	3
Transformer System (TS)	0.1297	4
Gas Cleaning System (GCS)	0.1193	5
Cooling System (SP)	0.1168	6
Electrode System (ES)	0.1152	7
Rotary Kiln (RK)	0.1149	8

Degree of Sophisticated Humanware

The object of observation of humanware components at PT Sebuku Iron Lateritic Ores is the company's employees who have been classified based on the level of position in each laterite iron ore processing process, namely the Rotary Kiln and Electric Arc Furnace. Starting from the level of workers, technicians, coordinators, supervisors/assistant managers, to executives.

Tabel 4. Degree of Sophisticated Humanware

Component	Weight	Priority
Production Operator (OP)	0.1322	1
Ahli Metallurgy (AM)	0.1239	2
Engineering Manager (MT)	0.1218	3
Supervisor (SV)	0.1113	4
Senior Technician (TS)	0.1098	5
Head of Operations Division (KDO)	0.1029	6
Director of Operations (DO)	0.1016	7
Production Supervisor (SP)	0.0999	8
Maintenance Technician (TP)	0.0966	9

Degree of Sophisticated Infoware

Based on Table 5, the results of the assessment of the degree of sophistication of infoware show that the lower limit of the degree of sophistication lies in basic information, namely providing a general understanding of the use of technology score 2, which is categorized as "low" level. Meanwhile, the upper limit is achieved by evaluative and strategic information, namely information that assesses the efficiency and sustainability of production facilities with a score of 8, which is included in the "high" category.

Tabel 5. Degree of Sophisticated Infoware

No	*Infoware*		Score	
1	Information that provides a general understanding of the use of iron ore refining technology (getting to know the facts)	1	**2**	**3**
2	Information that provides an understanding of the operation of iron ore refining technology (outlining the facts)	2	3	4
3	Information that allows the selection and installation of equipment (specifying facts)	3	4	5
4	Information on the efficiency of the use of the facility (using facts)	4	5	6
5	Information on improving understanding of facility design & operation (understanding the facts)	5	6	7
6	Information that allows for the development & improvement of the system (generalizing the facts)	6	7	8
7	Information for assessment of facilities (fact-checking)	7	**8**	9

Degree of Sophisticated Orgaware

The results of the assessment of the degree of sophistication of Orgaware in the rotary kiln system ranged from a score of 2 to 8. The lower limit is indicated by the business framework, indicating that the foundations of the organization are still weak. While the upper limit is achieved by Leading, it reflects strong leadership.

State of the Art Assessment (Up-to-Date Level)

State of The Art (SOTA) or the level of up-to-date is one of the stages of technology assessment in the technometric method to determine the position of a company in the range of degrees of sophistication. Therefore, a SOTA assessment was carried out on the transformation of iron ore refining technology using PT Sebuku Iron Lateritic Ores' rotarry kiln and electric arc furnace in detail.

State of The Art (SOTA) Technoware

Rotary Kiln

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value on *the technoware* component of the rotary kiln *process* is 0.8055, which means that the level of technological up-to-date is relatively high.

Electric Arc Furnace

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value in the *technoware component of the* electric arc furnace *process* is 0.8167 which means that the level of technological up-to-date is relatively high.

State of The Art (SOTA) Humanware

Rotary Kiln

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value on *the humanware* component of the rotary kiln *process* is 0.5889. This value is in the category of intermediate up-to-date, which means that there is still room for improvement, especially in strengthening teamwork, discipline, and cross-sectional collaboration.

Electric Arc Furnace

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value in the *humanware* component *of the electric arc furnace* process is 0.5889, which reflects that the level of up-to-date in terms of human resources is the same as that of *a rotary kiln*.

State of The Art (SOTA) Infoware

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value in the *infoware* component is 0.720. This shows that the company's *infoware* (I) is at a high level, although still below the level of technoware up-to-date, but higher than *infoware,* so it can be stated that SOTA-T > SOTA-I > SOTA-H.

State of The Art (SOTA) Orgaware

Based on the results of the SOTA assessment or the level of up-to-dateness, the SOTA value in the *orgaware* component is 1.0. This indicates that *the company's orgaware* (O) has been at the maximum level in supporting the successful implementation of technology and work systems. The maturity level of this *orgaware* is significantly higher compared to the other three components, namely SOTA-O > SOTA-I > SOTA-T > SOTA-H.

Calculation of the Contribution of Technology Components

Rotary Kiln

that the value of the technological contribution of each component that makes up the *rotary kiln* process shows the following order of contribution: *technoware* (T) > *orgaware* (O) > infoware (I) > *humanware* (H) or a total of 0.7373> 0.8889> 0.7100> 0.5296.

Electric Arc Furnace

that the value of the technological contribution of each constituent component in *the Electric Arc Furnace* (EAF) process shows the following order of contribution: *orgaware* (O) > *technoware* (T) > *infoware* (I) > *humanware* (H), with the contribution value of 0.8889 > 0.7856 > 0.7100 > 0.5494.

Assessment of the Intensity of Contribution of Technology Components

The intensity of the contribution of technology components (β) to PT Sebuku Iron Lateritic Ores was obtained using a pairwise comparison matrix or *Analytical Network Process* (ANP), which conducted a pairwise comparison of each of the criteria of the specified technology components.

Table 6. Results *of the* Assessment of the Intensity of Technology Contribution

Technology Components	Value of Intensity of Technology Contribution
1. Technoware (T) EAF	0.2450
2. Technoware (T) RK	0.1562
3. Humanware (H)	0.2271
4. Orgaware (O)	0.1922
5. Infoware (I)	0.1795

Technology Contribution Coefficient Rotary Kiln

The *Technology Contribution Coefficient* (TCC) value for the *rotary kiln process* is 0.7588, indicating that the system is in the high category, close to the classification of modern technology. The largest contribution came from *the orgaware* 0.8889 with an intensity of 0.1922, confirming the importance of the organization's role in the success of technology. *Technoware* 0.7856 also contributes significantly through equipment and production systems. *Infoware* 0.7100 supports data-driven decision-making, while *humanware* 0.5296 is the lowest, demonstrating the need to increase human resource capacity. Overall, strengthening organizational systems, modernizing equipment, and improving human competencies are key to pushing TCC towards a sustainable modern technology category.

Technology Contribution Coefficient Electric Arc Furnace

The *Technology Contribution Coefficient* (TCC) value for the *Electric Arc Furnace* process is 0.7563, which shows that the level of technological maturity is in the high category, close to modern classification. The largest contribution came from *technoware* 0.2450, followed by *orgaware* 0.1922) *infoware* 0.1795, and *humanware* 0.2271. These results show that key equipment and organizational systems are very dominant in supporting technological processes, while strengthening the capacity of human resources and information systems still needs to be improved. Overall, the EAF system has shown good technological integration. The next development focus can be directed to improving human resources, modernizing information systems, and strengthening the organization to encourage the achievement of a fully modern and sustainable technology ecosystem.

Map of the Fourth Relationship of Technology Components

A map of the relationship between the four technology components based on a comparison of the contribution value of each technoware*, humanware, inforware, and orgaware* (THIO) technology component.

***Assessment Internal Rate of Return* (IRR).**

IRR (*Internal Rate of Return*) assessment is to determine the company's internal return rate at the condition of the NPV of cash flow equal to the NPV of cash outflow.

Rotary Kiln

The results of the IRR assessment were carried out to determine the level of internal return on investment in iron ore processing technology using *Rotary Kiln*. This table shows the annual net cash flow after depreciation (*Net Income After Depreciation*) for 10 years, with an initial investment of IDR 900,064,000,000 in year 0. The calculation of IRR is carried out based on cash inflows from year 1 to year 10 which continues to increase from IDR 301,341,600,000 billion to reach IDR 719,822,458,880 billion at the end of the period. The IRR value obtained from the cash flow simulation is 37.90%. This IRR value shows that investment projects are much more profitable compared to the *Minimum Attractive Rate of Return* (MARR) which is generally used as an investment feasibility standard, for example 12% or 15%. Therefore, *the Rotary Kiln* investment project is financially feasible and has the potential to provide a very competitive rate of return for the company, given its IRR value which is almost three times the minimum standard usually used by investors or companies.

Electric Arc Furnace

IRR assessment results from iron ore refining technology investment projects using *the Electric Arc Furnace* (EAF) method. In year 0, an initial investment of IDR 900,064,000,000 was made, while annual cash inflows in the form of *Net Income After Depreciation* were calculated for the next 10 years of operation. *The value of Net Income After Depreciation* experienced significant growth from IDR 301,341,600,000 billion in the first year to reach IDR 719,822,458,880 billion in the 10th year. Based on the cash flow data, the calculation creates an *Internal Rate of Return* (IRR) of 65.09%. This IRR rate shows that the *Electric Arc Furnace* investment project has a very high internal rate of return, well above the commonly used minimum eligibility standard (MARR), such as 12% or 15%. With this amount of IRR value, the project can be categorized as very financially viable, provide a large profit margin, and provide high confidence for investors and related stakeholders in the long-term profitability of the investment.

Assessment Payback Period **(PbP)**

The assessment payback period (PbP) is to measure the level of return on investment carried out by PT Sebuku Iron Lateritic Ores, including the use of iron ore refining technology, *rotary kilns* and *electric arc* furnaces. Therefore, it is necessary where the condition of cash flow is equal to the cash flow out (NPV = 0) or the investment period range will experience BEP (*Break Event Point*)

Rotary Kiln

The *Net Present Value* (NPV) value reached zero between the 3rd and 4th years, with interpolation showing a payback period of 3.6987 years or around 3 years and 8 months. This means that the investment in iron ore refining technology using *rotary kilns* by PT Sebuku Iron Lateritic Ores interpolation is carried out as follows:

n1 = 3 NPV 1 = -114,556,022,906

n1 = 4 NPV 2 = 49,493,655,442

$$n = 3 + \frac{0-(NPV1)}{NPV2-NPV1} x(n2-n1)$$

n = 3,6987

where it reaches break-even point (BEP) faster than the projected 10 years of investment, so it is considered financially feasible and has an efficient period of return. The *Net Present Value* (NPV) value reaches zero between the 2nd and 3rd years. Through interpolation, it is obtained that *the Payback Period* (PbP) occurs in the 2nd year 2095 or around the 3rd month of the 2nd year. This shows that the iron ore refining technology using *an electric furnace* by PT Sebuku Iron Lateritic Ores interpolation is carried out as follows :

n1 = 2 NPV 1 = -66,162,063,393

n1 = 3 NPV 2 = 249,652,963,765

$$n = 2 + \frac{0-(NPV1)}{NPV2-NPV1} x(n2-n1)$$

n = 2,2095

able to return the investment faster than other methods, which is less than 2 years and 3 months. This result gives an idea that *electric furnace technology is* very efficient in terms of return on capital and has the potential to be financially superior.

***Assessment Benefit Cost Ratio* (B/C)**

Benefit Cost Ratio (B/C) is 0.9905, which means > 1. This shows that the iron ore processing project using *rotary kiln technology* is not financially feasible because the value of the benefits obtained during the project life is not able to cover the initial investment costs. *The Benefit Cost Ratio* (B/C) value for *electric arc furnace technology* is 0.9905, which means that the project is not economically feasible. The benefits obtained throughout the life of the project have not been able to cover the entire initial investment cost.

Sensitivity Analysis

Sensitivity analysis is an analysis model that is carried out to find out the magnitude of the level of contingency faced by the company, as well as how much influence each production parameter has on changes in the performance of the production system in creating profits.

Analysis of Interest Rate Sensitivity with NPV

In the research conducted, sensitivity analysis used the tribal level
the benchmark interest rate based on the average BI-Rate in 2023 is 5.5%. The results of the sensitivity analysis are the effect of increasing the benchmark interest rate on NPV obtained based on the investment in iron ore refining technology *for rotary kilns* and *electric arc furnaces* carried out by PT Sebuku Iron Lateritic Ores. Changes are made to the initial interest rate, by gradually increasing the interest rate on the initial investment until a negative NPV value is obtained.

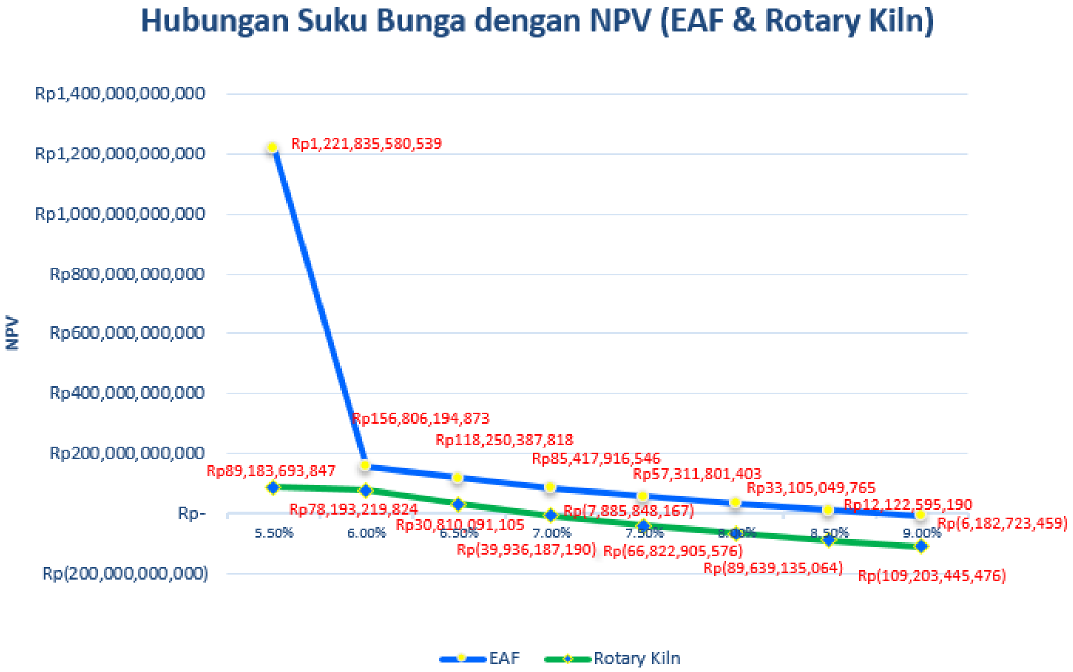

Figure 1. Chart of the Relationship of Interest Rates to NPV

In Figure 1, a graph of the limit of changes in interest rate increases in investments carried out by PT Sebuku Iron Lateritic Ores to the NPV value of *electric arc furnace* (EAF) technology is 8.5% with the NPV limit obtained is IDR 12,122,595,190. Meanwhile, in *rotarry kiln* technology, the limit of change in interest rate increase to the NPV value is 6.5% with the NPV limit obtained is IDR 30,810,091,105.

Price Sensitivity Analysis of *Sponge Iron* and *Pig Iron* by NPV

Table 7 shows the results of the analysis of the average sensitivity of *sponge iron* and *pig iron* prices (Rp/Ton) based on international price fluctuations that have occurred over the last 5 years with NPV values in rotary *kiln* and *electric arc furnace* iron ore refining technology. Changes were made to the average price *of sponge iron* and *pig iron* by gradually reducing the price of the initial investment until a negative NPV value was obtained.

Table 7. Price Sensitivity Analysis of *Sponge Iron* and *Pig Iron* with NPV

Product Price (Rp/Ton)	NPV	
	EAF	Rotary Kiln
8.000.000	1.221.835.580.539	
7.452.000	156.806.194.873	
6.904.000	118.250.387.818	89.183.693.847
6.356.000	85.417.916.546	78.193.219.824
5.808.000	57.311.801.403	**30.810.091.105**
5.260.000	33.105.049.765	(7.885.848.167)
4.712.000	**12.122.595.190**	(39.936.187.190)
4.164.000	(6.182.723.459)	(66.822.905.576)
3.616.000	(89.639.135.064)	(89.639.135.064)
3.068.000	(109.203.445.476)	(109.203.445.476)

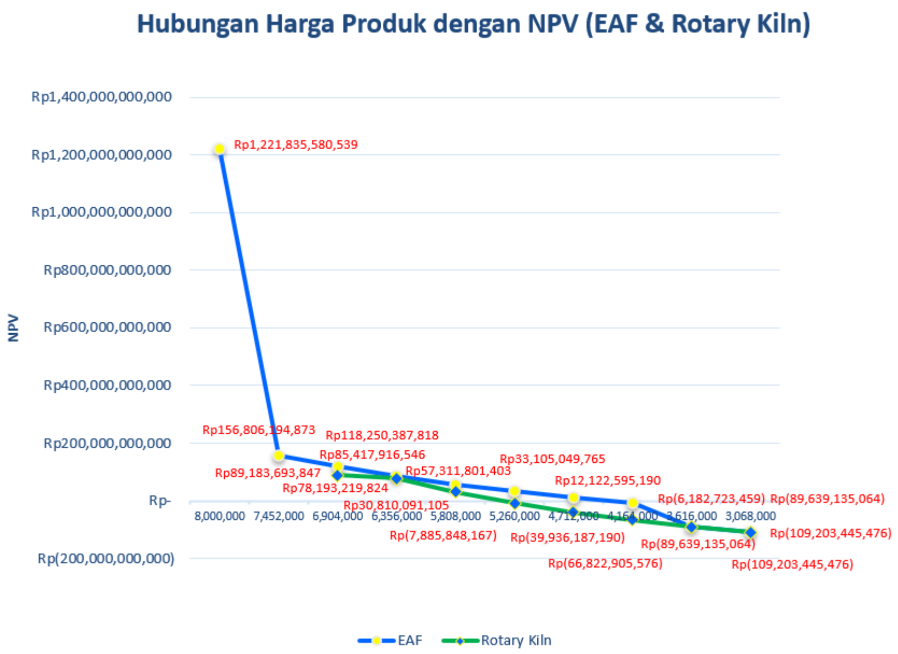

Figure 2. Chart of the Price Relationship *of Sponge Iron* and *Pig Iron* with NPV

Based on Table 7, a sensitivity analysis was carried out on fluctuations in the selling price of sponge iron and *pig iron* (Rp/Ton) in relation to the *Net Present Value* (NPV) value of investment in *rotary kiln* and *electric arc furnace* (EAF) technology. The price range used reflects the movement of international market prices over the past five years. The price decline is carried out in stages to evaluate the limits of the financial feasibility of the investment against market pressures. The results show that in *rotary kiln* technology, the NPV value remains positive until the selling price of the product reaches Rp 5,808,000/Ton, with an NPV of Rp 30,810,091,105. After this point, the NPV turns negative, showing that the minimum acceptable selling price (*Break-Even Price)* is slightly above Rp 5,260,000/Ton. Meanwhile, in *electric arc furnace* (EAF) technology, the NPV remained positive until the selling price reached IDR 4,712,000/Ton, with the last NPV of IDR 12,122,595,190. Below this price, EAF's NPV becomes negative, which means that EAF has stronger financial resilience to product price declines than *rotary kilns*.

Thus, it can be concluded that EAF technology is more tolerant of market price fluctuations and more competitive in low product price scenarios, whereas *rotary kilns* have a higher minimum price cap to remain financially viable.

Analysis of *Operational Expenditure* (OPEX) Sensitivity with NPV

Table 8 shows the results of the analysis of the average annual OPEX sensitivity of PT Sebuku Iron Lateritic Ores. The change is made to the average OPEX increase by increasing the OPEX percentage in the initial investment gradually until a negative NPV value is obtained.

Table 8. OPEX Sensitivity Analysis with NPV

OPEX %	NPV	
	EAF	**Rotary Kiln**
100%	1.221.835.580.539	89.183.693.847
105%	149.001.113.719	90.949.537.499
110%	95.753.633.243	**44.774.929.901**
115%	**42.506.152.767**	(1.399.677.697)
120%	(10.741.327.710)	(47.574.285.295)
125%	(63.988.808.186)	(93.748.892.697)
130%	(117.236.288.662)	(139.923.500.491)
135%	(170.483.769.139)	(186.098.108.089)

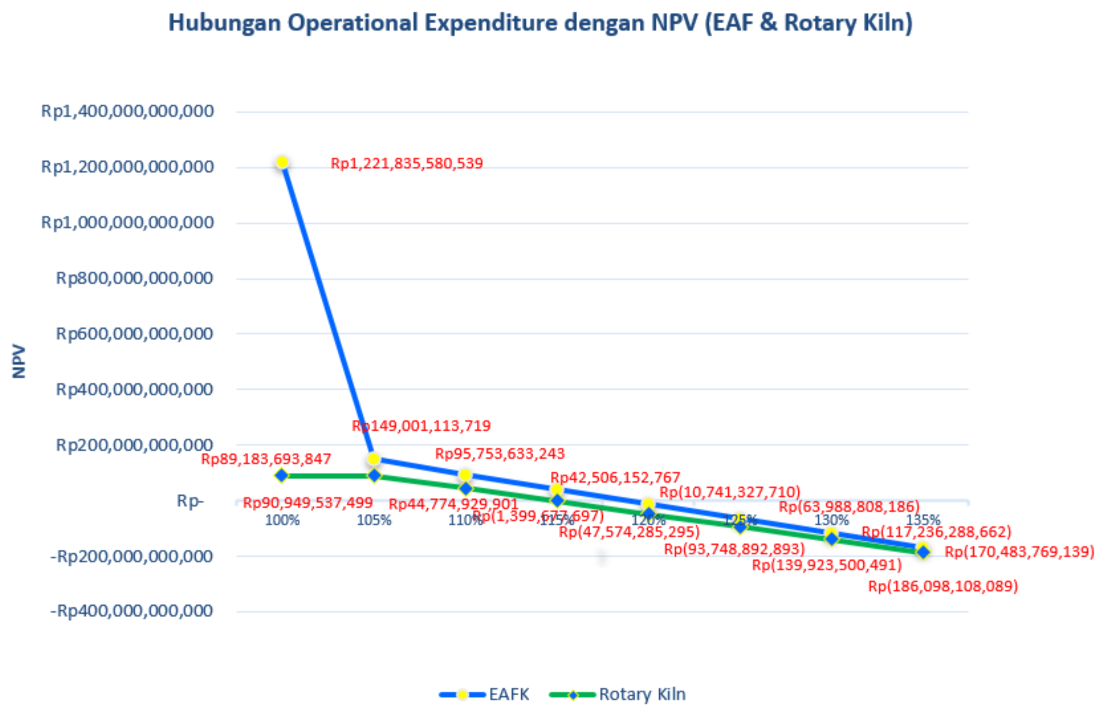

Figure 3. Chart of the Relationship of OPEX to NPV

Based on 8 and the chart of the relationship between OPEX and NPV, a sensitivity analysis was conducted to measure the impact of increased operating costs (OPEX) on the feasibility of investing in two technologies, namely *electric arc furnace* (EAF) and *rotary kiln*. OPEX values vary from 100% to 135%, with each point reflecting a simulated NPV based on an annual cost increase scenario. The results of the analysis show that in rotary *kiln* technology, the NPV value remains positive until the OPEX level reaches 110%, with an NPV of IDR 44,774,929,901. Above that limit, as at OPEX 115%, NPV turns negative, signaling that the maximum tolerance limit for OPEX increases has been exceeded. Meanwhile, EAF technology still maintains a positive NPV until OPEX reaches

115%, with the last positive NPV of IDR 42,506,152,767. After this point, the NPV value becomes negative. This indicates that in terms of resistance to increased OPEX, EAF technology has better flexibility than *rotary kilns*, allowing the project to remain financially viable under higher operational cost conditions.

The implications for managerial in this study are a form of study proposal that is used to provide recommendations or input to the *top management* of the company PT Sebuku Iron Lateritic Ores, where the party has the power to prepare programs related to the development and improvement of the optimization of resources owned by the company. Based on the results of the research carried out, the *top management* of PT Sebuku Iron Lateritic Ores has various recommendations or technical considerations as the basis for the preparation of a potential increase program to reduce the risk of *gaps* from the four technology components, namely *technoware, humanware, inforware,* and *orgaware* owned by each iron ore refining technology *rotary kiln* and *electric arc furnace*. Then the results of the research can also be considered by *top management* in determining the policy roadmap of effectiveness and efficiency in the allocation of the company's budget in transforming input technology into output.

CONCLUSION

This study evaluated the technometric readiness and economic feasibility of Rotary Kiln (RK) and Electric Arc Furnace (EAF) technologies for lateritic iron ore processing at PT Sebuku Iron Lateritic Ores (PT SILO), identifying both systems as semi-modern with Orgaware as the strongest component and notable gaps in Humanware and Inforware. It provided evidence-based recommendations for a gradual transition to EAF, emphasizing workforce skill development, digitalization, equipment modernization, and organizational strengthening. Economic analyses confirmed EAF as the more resilient and strategically viable option for long-term profitability and sustainability. This research advances integrated technometric and financial assessment methods in Indonesia's steel industry and lays the groundwork for future studies to develop optimization models, implementation strategies, and policy frameworks aimed at enhancing national self-sufficiency, technology adoption, and sustainable industrial growth. Future research could focus on specific implementation pathways and the impacts of digital transformation on operational efficiency in the steel sector.

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