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FINANCIAL FEASIBILITY ANALYSIS IN CIRCULAR ECONOMY PROJECTS: A CASE STUDY OF SALT WASTE UTILIZATION THROUGH CLEAN PRODUCTION TECHNOLOGY

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ABSTRACT

Background: The salt industry in Madura is one of the largest contributors to meeting national salt needs. Although salt has great potential as an economic resource, the conventional salt production process produces waste that has not been optimally managed. As a salt production center, the amount of salt waste produced by the salt production process in Madura is very abundant in one season. However, there is no innovative and integrated solution to process this waste so that it can produce products with economic value.
Purpose: This study aims to investigate the financial feasibility of salt waste utilization projects through the implementation of clean production technology as an integrated part of the circular economy. The existence of this research is expected to provide innovative solutions in the utilization and management of salt waste and reduce the environmental impact that can be caused by the salt production process.
Design/methodology/approach: This study adopts a quantitative approach with a descriptive method, and was carried out in salt production centers in the Madura region in the period from May to August 2025. The data used includes primary and secondary data, which are collected through various techniques, such as observation, interviews, surveys, documentation, and literature studies. The financial feasibility analysis was conducted using four main metrics: Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Benefit Cost Ratio (BCR).
Findings/Results: The results of the study show that the bittern waste utilization project has significant economic potential and is able to create new added value for the salt industry. These activities can provide competitive financial benefits, relatively low risk, and a fast return on capital. In addition to economic benefits, the integration of circular economy principles in the implementation of clean production also makes a real contribution to reducing liquid waste disposal, resource use efficiency, and opportunities to improve social welfare through the creation of new jobs.
Conclusion: Thus, the use of bittern waste through the circular economy strategy is declared financially feasible while supporting the goal of sustainable industrial development.
Originality/value (State of the art): Theoretically, the implementation of clean production technology is not only projected to increase production efficiency and provide economic added value, but also to support environmental preservation and sustainability. Therefore, the results of this research are expected to be a reference for the development of sustainable business models that are in line with the principles of the circular economy.

Keywords: financial feasibility, salt waste, bittern, circular economy, clean production

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INTRODUCTION

The salt industry sector in Indonesia, especially in the Madura region, plays a crucial role in supporting the local and national economy. National salt production reaches 2.04 million tons per year, with most of it coming from production centers in East Java, including Madura (Kementerian Kelautan dan Perikanan Republik Indonesia, 2024). Madura is the largest contributor to national salt production, as in 2024, Madura will contribute 34.3% of the total national salt production (Humas Direktorat Jenderal Pengelolaan Kelautan dan Ruang Laut, 2024). However, behind this great economic potential, the conventional salt industry faces serious problems related to waste management. The salt production process, which generally relies on seawater evaporation, produces solid and liquid waste. This waste, which is rich in concentrations of sodium chloride (NaCl) and other minerals, is often dumped into the environment. This practice leads to severe environmental degradation, including increased soil and water salinity, damage to coastal ecosystems, and decreased fertility of farmland around salt ponds (Lv et al. 2024). These ecological consequences not only threaten biodiversity but also have a direct impact on the well-being of communities that depend on the agriculture and fisheries sectors (Meehan et al. 2023).
Globally, sustainability issues have driven a paradigm shift from a "take-make-throw" linear economic model to *a circular economy*. This model, promoted by institutions such as the Ellen MacArthur Foundation, emphasizes on the reuse, recycling, and recovery of resources to minimize waste and maximize economic value (Ellen MacArthur Foundation, 2015). The circular economy is a system solution framework that tackles global challenges like climate change, biodivesity loss, waste, and pollution (Rapati et al. 2023).This framework offers a relevant solution for the salt industry, where waste can be viewed as an untapped resource. The application of this concept requires technological innovation that is able to turn waste into value-added products. One of the most promising approaches is clean production technology, which focuses on process efficiency and waste minimization at the source (Zhang et al. 2017).

In the context of salt waste, research has identified its potential as a raw material for a variety of products, including industrial chemicals, construction materials, and fertilizers (Janani & Kumar, 2018) (Pranoto et al. 2024). Despite this potential, there are still significant gaps in the literature, particularly related to financial and technical feasibility studies in Indonesia. The implementation of salt waste processing technology requires substantial initial investment, so financial feasibility analysis is crucial. Therefore, this study aims to comprehensively examine the financial feasibility of the project to utilize salt waste into organic fertilizer in the Madura area. By analyzing financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Benefit Cost Ratio (BCR), this study will provide a scientific foundation and empirical data that can be used by decision-makers, investors, and industry players to adopt more sustainable business models. Thus, this research is expected to show that environmental protection and economic benefits can go hand in hand, in line with the principles of sustainable development.

This research has a significant novelty, which distinguishes it from previous studies, especially in the context of the salt industry in Indonesia. *The novelty* in this research lies in a holistic and multidimensional approach that integrates three crucial aspects, namely environmental sustainability, technological innovation, and financial feasibility analysis. In contrast to previous studies that tended to focus on one aspect in isolation, this study comprehensively integrates the principles of circular economy and the application of clean production technologies in the specific context of the salt industry in Indonesia. Although the problem of industrial waste has been widely studied, the solution offered in this study is unique because it specifically identifies the potential of salt waste as a raw material for organic fertilizers. The focus on this final product is not just a waste mitigation effort, but also a dual solution that contributes to increasing soil fertility and reducing dependence on chemical fertilizers. In addition, substantial novelty lies in its in-depth, empirical data-driven analysis of financial viability. This research not only tests technical feasibility, but also provides a robust financial evaluation using standard metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP). This analysis fills in the existing literature gaps and provides a theoretical and practical foundation for investors and policymakers to adopt sustainable business models. Thus, this research not only makes a scientific contribution, but also offers an applicative model that can drive the transition of the salt industry towards more efficient and environmentally friendly practices.

The problem-solving approach in this study was prepared by considering the characteristics of the people's salt industry and the dynamics of the production process. The first step is taken by identifying the fundamental problem, namely the non-optimal use of salt waste that actually has economic value, and the limited use of clean production technology at the operational level. This identification does not only rely on a review of documents or literature, but also pays attention to field findings and input from industry players, so that the context of the problem can be understood more realistically.

After the scope of the problem is clarified, the research turns to the formulation of alternative solutions that are relevant to the actual conditions. At this stage, the characteristics of waste, the readiness of production infrastructure, and the possibility of integrating clean production technology are systematically analyzed. The results of the analysis then become the basis for compiling a financial scenario that represents the implementation options for the circular economy project.

The next stage is to conduct a financial feasibility assessment through the calculation of key indicators such as NPV, IRR, Payback Period, and Profitability Index. This calculation uses estimated costs and benefits constructed based on primary and secondary data. The focus is not just on generating numbers, but ensuring that each indicator reflects reasonable and methodologically accountable operational conditions.
In addition, sensitivity analysis is used to assess how changes in key variables, e.g. fluctuations in energy prices, production volumes, or investment costs may affect the feasibility of a project. In this way, the research not only presents static financial results, but also provides an overview of the level of vulnerability of projects to uncertainty.

Overall, the problem-solving approach used combines an integrated understanding of context, technical analysis, and financial evaluation. This approach allows the study to assess the potential for the implementation of clean production technology in salt waste management more comprehensively, both in terms of its economic benefits and operational feasibility.

This study aims to find out whether the application of clean production technology in the utilization of salt waste is feasible from a financial point of view. So far, salt waste is often not processed and is only seen as a production residue, so this study tries to see the extent to which the waste can provide added value that is beneficial to the industry. In an effort to answer these goals, the study examines the potential of salt waste and the clean production technologies that allow it to be used, calculates the costs and benefits that may arise from its implementation, and evaluates financial feasibility through indicators such as NPV, IRR, Payback Period, and Profitability Index. Sensitivity analysis is also conducted to understand how the feasibility of the project will change in the event of fluctuations in cost, production volume, or price. Thus, this research is expected to provide practical input for industry players and related parties in developing waste utilization more effectively and sustainably.

METHODS

The research was conducted in a salt-producing region in Madura, East Java. Two regencies were selected as research locations, Sampang and Pamekasan, due to their significant salt production. It lasted four months, from May to August 2025.

This study uses a combination of primary and secondary data so that the analysis of financial feasibility can describe the conditions that actually occur in the field. Primary data is obtained through direct observation of the salt production process, including the pattern of waste formation, its physical characteristics, and operational costs that arise during production activities. In addition, informal interviews with industry players and workers at the production site were conducted to obtain information about technical constraints, current waste utilization levels, and their readiness to adopt clean production technology. This primary data is the basis for making more realistic cost and benefit assumptions.

Meanwhile, secondary data was collected from technical reports, previous research, official government publications on the salt industry, and literature discussing the application of clean production technology in similar sectors. Some supporting data, such as energy prices, labor wages, and market projections, are obtained from national statistical sources as well as relevant company documents. All of these data were used to build NPV, IRR, Payback Period, and Profitability Index calculation scenarios, as

well as to build sensitivity models for key variables.

The use of these two types of data allows research to present an analysis that is not only theory-based but also reflects operational reality, so that the results of the resulting feasibility evaluation are more reliable and can be accounted for academically and practically.

Data collection in this study was carried out through a field approach that focuses on the salt waste treatment process and its economic potential in the clean production system. The main data is obtained through direct observation at the operational stages that produce waste, including the volume of waste, the physical and chemical characteristics of the waste, and the flow of its utilization into value-added products. This observation was carried out by following the production process sequentially, so that the researcher could record energy needs, water use, equipment involved, and efficiency changes when clean production technology was applied.

In addition to observations, researchers collected data through in-depth interviews with managers, production operators, and parties involved in the waste processing process. These interviews are used to obtain information that is not recorded in formal documents, such as technical constraints, actual costs that arise in the field, or process adjustments made to improve the quality of the treated waste. Financial data required for the feasibility analysis, including initial investment costs, operational costs, estimated equipment life, projected revenue from waste derivative products, and potential savings from process efficiency, were obtained through internal company documents, production cost reports, and material and energy purchase records.

To complete the primary data, the researcher used secondary data sourced from industry reports, production cost standards in the salt sector, previous studies related to the implementation of clean production, and regulations governing industrial waste management. The combination of observational data, interviews, and financial documents allows researchers to compile a more accurate picture of the technical performance and economic feasibility of the use of salt waste within the framework of the circular economy.

The data analysis in this study was carried out by integrating the technical evaluation of the salt waste treatment process and the financial calculations needed to assess the feasibility of the circular economy project. The analysis stage begins with reducing and compiling field data related to waste volume, raw material characteristics, energy needs, and efficiency changes that arise after the application of clean production technology. This technical data is processed to produce estimates of production capacity, daily operational needs, and potential outputs that can be used as a basis for calculating costs and economic benefits.

Once the technical data has been mapped, the next stage is the analysis of financial feasibility using a number of standard investment indicators. Initial investment costs, annual operating costs, residual equipment value, and projected revenue from waste derivative products are included in a calculation model that includes Net Present Value (NPV), Internal Rate of Return (IRR), Benefit–Cost Ratio (BCR), and Payback Period (PP) (Nugroho et al. 2025). This analysis is carried out by considering the time value of money, production growth scenarios, and possible cost fluctuations due to changes in operational conditions. The calculation also involves sensitivity analysis to identify the variables that have the most influence on feasibility, such as changes in the selling price of waste-based products, increased energy costs, or decreased production capacity.

In addition, the data were compared triangulatively with industry literature, cost standards, and research findings related to waste utilization and clean technology. This approach allows researchers to ensure that the results of the calculations not only rely on local assumptions, but also meet the technical and economic reasonableness recognized in industry practice. Through a combination of technical analysis and complementary financial evaluation, this study produces a more comprehensive picture of the extent to which salt waste utilization projects within the framework of the circular economy are feasible to be implemented commercially.

The framework of thought in this study departs from the assumption that the circular economy approach opens up opportunities to transform salt waste that previously had no added value into a new economic source through the application of clean production technology (Figure 1). With this foundation, the research maps the relationship between the technical process of waste treatment and the financial consequences that arise from each stage of production. Technical data regarding waste characteristics, resource needs, and potential outputs are processed into cost and benefit components which

are then evaluated using financial feasibility indicators, such as NPV, IRR, BCR, and Payback Period. This framework places clean production technology as a key factor that affects process efficiency, operational cost burden, and the quality of processed products. Furthermore, the financial projections generated from the calculation model were tested for sensitivity to critical variables to see the level of project resilience in various operational scenarios. Thus, this framework provides a structured analytical flow, ranging from the basic concept of the circular economy, technical data of waste treatment, calculation of economic benefits, to financial feasibility assessments that ultimately lead the research to conclusions regarding the economic value and sustainability of the project.

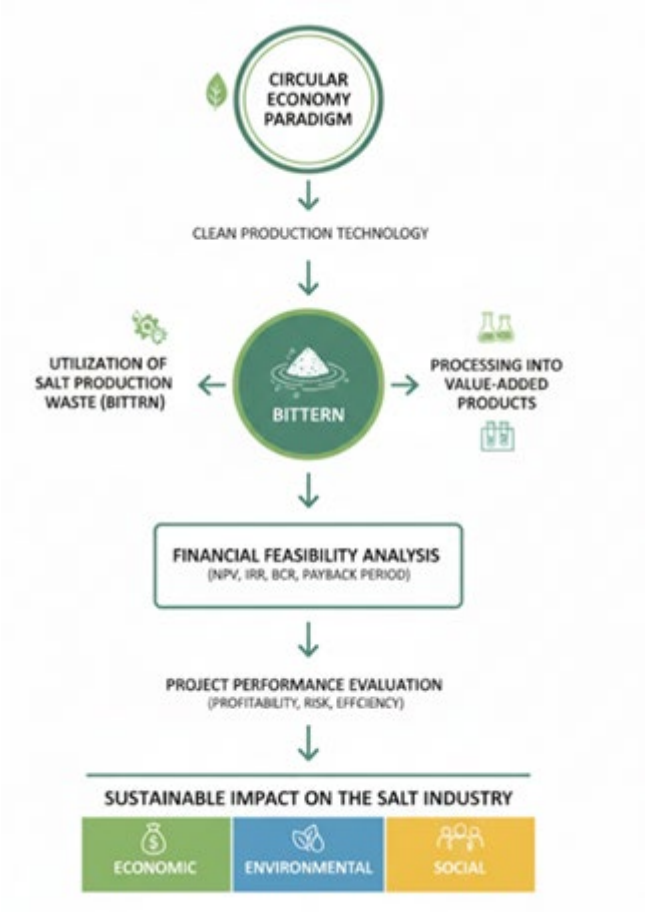

Figure 1. Framework of thought

RESULTS

Financial Feasibility Analysis

In the context of processing bittern waste into value-added products, the analysis shows that this business model is not only financially feasible but also highly relevant to the circular economy paradigm. A circular economy is defined as a regenerative system in which resource inputs, waste, emissions, and energy leakage are maximally reduced (Geissdoerfer et al. 2017). Furthermore, it is explained that "reduce-reuse-recycle" activities are the core of the circular economy concept (Kirchherr et al. 2017). In this study, waste is redivided into new raw materials, so it's clear that the project is implementing reduce and reuse.

Furthermore, the clean production approach is highly relevant for explaining how bittern processing technology improves financial performance while maintaining environmental sustainability. Net production is defined as "continuous application of an integrated preventive environmental strategy to processes, products, and services to increase efficiency and reduce risks to humans and the environment" (Shi et al. 2021). Thus, the salt waste treatment process through efficient technology reduces material and energy consumption, as well as reduces waste and emissions. This significantly reduces operational costs and regulatory risks, thereby increasing the project's financial feasibility.

In 2024, national salt production reached 2 million tons, of which 1.7 million tons was community-produced salt. This number decreased compared to the previous year, which reached up to 2.5 million tons, with community-produced salt amounting to 2.2 million tons (*Kementerian Kelautan Dan Perikanan*, 2025). Madura has three potential areas classified as the largest salt-producing regions, namely Pamekasan, Sampang, and Sumenep. This study was only conducted in two regencies, namely Sampang and Pamekasan, because they are considered sufficient to represent the salt production conditions in Madura. The salt land area in Pamekasan is 1,016.27 hectares, and the salt land area in Sampang is 3,100.29 hectares (*Kementerian Kelautan Dan Perikanan*, 2025). The height of the remaining water from the final salt production process is estimated at 0.5 cm, multiplied by 2 plot areas, which will yield the volume of bittern water in each regency. Based on the estimated bittern data generated by calculating the

land area in Pamekasan and Sampang Regencies, the volume of waste that can be reused reaches 102,914 liters per season (Table 1). This waste is then processed into products with selling value through the clean production process. The selling price of the product is set at IDR 20,000 per liter, so it has the potential to generate a gross income of IDR 2,058,280,000 per production season. On the other hand, the total operating costs incurred for the procurement of raw materials, packaging, labor wages, marketing, transportation, and licensing reached IDR 543,308,500. The largest cost component came from the purchase of raw materials, which was IDR 308,742,000, and packaging costs of IDR 205,828,000, which reflects that the efficiency of input supply and packaging design will greatly affect business profitability. The comparison between revenue and costs shows a high profit margin, with a gross profit of IDR 1,514,971,000 per production season. This figure illustrates a very significant profitability, especially since the main source of raw materials is the waste of the salt industry, so that production costs can be reduced.

Based on financial analysis, the total revenue of IDR 2,058,280,000 per season, with operating costs of IDR 543,308,500, shows a very large margin and shows that this model touches on aspects of economic efficiency as well as environmental sustainability. The figures show that every dollar of cost invested returns a lot of revenue, which reinforces the argument that these ventures are not only "viable" but also "superior" in the context of green business.

Net Present Value (NPV) Calculation Results

NPV is defined as the difference between the present value of cash inflows and the present value of the expected cash outflows of an investment or project (Gaspars-Wieloch, 2019). NPV is understood as the difference between the present values of cash inflows and cash outflows analysed over some time (Dobrowolski & Drozdowski, 2022). This concept is fundamental in investment decision-making because it takes into account the time value of money, which is that one rupiah owned now has a higher value than one rupiah received in the future.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I0$$

Where CF_t (net cash flow year t), r (Discount rate), and I_0 (initial investment). If the NPV is > 0, then the project has added value and is worth taking. NPV = 0 then there is no added value and NPV < 0, then the project reduces the value.

Based on the results of the calculation of investment feasibility indicators, the bittern waste treatment project shows a very high level of profitability. The Net Present Value (NPV) of IDR 6,858,336,040 (Table 2) is well above the initial investment value, which means that the project provides significant economic added value throughout the life of the business. This positive and large NPV shows that the cash receipts generated in the future are able to offset the entire cost of capital with a very noticeable overvalue, so that the investment is not only profitable, but also has the capacity to generate a high accumulation of wealth for investors.

Table 1. Estimated total cost and total revenue

Information	Sum	Price	Unit	Total
Gross revenue	102.914	IDR20,0000	Litre	IDR2,058,280,000
Operating Costs				
Marketing Costs	4	IDR250,000	Parcel	IDR1,000,000
Transportation Costs	100	IDR 10,000	Litre	IDR1,000,000
Transportation Costs	10	IDR100,000	Person	IDR1,000,000
Packaging Cost	102.914	IDR 2,000	Litre	IDR205,828,000
Wages	102.914	IDR250	Litre	IDR25,728,500
Purchase of Raw Materials	102.914	IDR 3,000	Litre	IDR308,742,000
Licensing	1	IDR 5,000,000	River	IDR5,000,000
Equipment	10	IDR500,000	Unit	IDR5,000,000
Total Cost				IDR543,308,500
Gross Profit	IDR 1,514,971,000			

Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is one of the main methods in investment evaluation that measures the percentage discount rate at which the net present value (NPV) of the entire project's cash flow becomes zero. This means that IRR is the rate of return that is expected to be earned if a project is executed according to the estimated cash flow. It can be defined as a discount rate that makes the net present value (NPV) of all cash flows from an investment equal to zero (De Albornoz et al. 2018).

$$\text{NPV} = \sum_{t=1}^{5} \frac{CF_t}{(1+r)^t} - 543.308.500 = 0$$

The Internal Rate of Return (IRR) indicator reached 291% (Table 3), which shows that the rate of return on investment far exceeds the discount rate used in the analysis. The higher the IRR value above the required minimum rate of return, the smaller the level of investment risk and the stronger the feasibility of the financial decision.

Payback Period (PP) Calculation

The Payback Period (PP) is the period of time it takes to return the initial investment from the project's net cash flow. In other words, PP measures how long the invested capital will 'return' before the project starts generating net profits. Payback Period is identified as one of the most widely used capital budgeting techniques in industry practice (Kurniatun et al. 2023).

Payback Period = Initial Investment : CF Year 1
= 543,308,500 : 1,500,000,000
= 0.36 years (4-5 months)

The very short payback period of 0.36 years, or less than five months, indicates that this business can return the initial capital quickly, thereby increasing investor confidence and minimizing potential losses due to market uncertainty. It also emphasizes that this project has a strong cash flow since the beginning of operations, thus minimizing the need for additional financing.

Calculation of Benefit Cost Ratio (BCR)

BCR is a ratio that measures the economic feasibility of a project by comparing the present value of the expected benefits to the present value of the costs incurred (Frej et al. 2021). If BCR > 1, then the benefits in excess of the project cost are considered economically feasible. In contrast, BCR <1 signifies costs greater than the benefits of the project are not feasible.

BCR = PV Benefit : PV Cost
= 7,401,644,540 : 543,308,500
= 13.62

Table 2. Net Present Value (NPV)

Year	Net Cash Flow (CFt¬)	Discount Factor (10%)	Present Value (PV)
1	1,500,000,000	0.9091	1,363,636,363
2	1,750,000,000	0.8264	1,446,197,916
3	2,000,000,000	0.7513	1,502,562,604
4	2,250,000,000	0.6830	1,536,999,915
5	2,500,000,000	0.6209	1,551,747,742
Total PV			IDR7,401,644,540
NPV			IDR6,858,336,040

Table 3. Gradual iteration

Discount Experiment (r)	NPV Results	Status
100%	Large positive NPV	Not yet
200%	Positive NPV	Not yet
291%	NPV is close to zero	IRR Point
300%	NPV starts negative	Skip

The Benefit Cost Ratio (BCR) value of 13.62 shows that every Rp1 cost invested in this business produces an economic benefit of Rp13.62. This ratio far exceeds 1 figure provides solid evidence that the project is highly efficient from an economic point of view. The overall results of the financial feasibility indicators show that the use of bittern waste is not only environmentally friendly because it reduces pollution, but also makes a real sustainable economic contribution to salt industry players. With this very dominant financial performance, the project deserves to be recommended for development on a larger scale, and can be used as an innovative business model in realizing industrial transformation towards a more profitable clean production and circular economy approach in the long term.

Value Proposition Circular Economy

The use of bittern waste as an alternative raw material in the salt industry presents a significant value proposition from an economic perspective. Waste that was previously considered a residue with no economic value and incurred a handling burden can now be converted into value-added products through the recovery process of minerals, especially magnesium.Potential extraction and reuse of minerals from bittern is able to generate high economic value and reduce industrial dependence on primary raw materials (Bagastyo et al. 2021). These findings are in line with the results of the financial analysis in this study, which shows strong economic feasibility, so that the value proposition from the economic side has a clear quantitative foundation.

In addition to economic benefits, the application of the clean production approach in processing bittern into value-added products strengthens the value proposition from the operational side. This approach focuses on resource use efficiency, prevention of waste at the source, and reducing environmental impact during the production process. Waste utilization technology based on clean production processes can improve production efficiency while improving environmental performance through residue and emission minimization (Pan et al. 2023). This has implications for long-term operational stability and reduced financial risks due to potential environmental sanctions and regulations, which ultimately strengthen business competitiveness.

Furthermore, in the context of industrial transformation towards a circular economy, the use of bittern waste provides a broader value proposition covering economic, social, and environmental aspects simultaneously. The circular economy emphasizes the importance of maintaining material value in the economic cycle for as long as possible through strategies such as reuse, recovery, and waste valorization to create new value streams.Utilization of Bittern is a concrete example of closing the loop in the salt industry, which not only increases added value but also contributes to the reduction of waste and emissions (Bagastyo et al. 2021). Thus, the value proposition in this study not only increases business profitability but also supports the goal of sustainability and the development of industries that are more resilient to market and environmental dynamics.

The Impact of Clean Production Technology

The application of the circular economy concept in the treatment of bittern waste provides a strong value proposition in the production system of the salt industry. The circular economy emphasizes the importance of maintaining material value in order to remain in the economic cycle through strategies of reuse, reprocessing, resource recovery, and the creation of higher value derivative products. Thus, economic value is not lost in the form of waste, but is able to be converted into productive industrial commodities. In the context of this study, bittern waste, which was previously seen as only a leftover production with no economic value, is now repositioned as a strategic resource that has the potential to generate additional income and reduce the industry's dependence on conventional raw materials. This paradigm transformation shows that waste treatment activities are not a purely regulatory obligation, but an integral part of a business strategy to increase business competitiveness and sustainability. In addition to generating economic benefits, the use of bittern based on clean production provides a significant value proposition in operational aspects. Clean production is oriented towards efficiency and pollution prevention from the early stages of the production process by optimizing the flow of materials and energy. In this case, the processing of bittern into value-added products is carried out through stages that reduce energy consumption and minimize residues, so as not to generate secondary waste that has the potential to pollute the environment. The application of this more efficient technology has implications for reducing operational costs directly, especially in the case of liquid waste management costs that have

been burdening the salt industry. Thus, the resulting value proposition is not only in the form of increased production capacity and output quality, but also in the form of long-term cost reductions that can increase the profit margins of the business on a sustainable scale.

Furthermore, the project's value proposition can also be analyzed from the perspective of investment feasibility, which is reflected in the financial indicators that have been calculated. A high Net Present Value (NPV) indicates that the project provides significant accumulated added value throughout the life of the business. Meanwhile, a very large Internal Rate of Return (IRR) shows that the level of profit generated far exceeds the required rate of return, so the investment risk is low. The Benefit Cost Ratio (BCR) that is far above one indicates high economic efficiency, where every rupiah of cost results in multiple benefits. Coupled with a payback period (< 1 year), the project exhibits business characteristics with high liquidity and low risk sensitivity. Overall, these indicators reinforce the argument that the use of bittern is a sustainable value proposition strategy from a financial perspective. In the environmental and social dimensions, the implementation of circular economy strategies through the use of bittern is able to reduce the burden of liquid waste pollution in coastal areas and reduce emissions from waste disposal. With the increase in value-added processing activities, the opportunity to create new jobs in the collection, processing, and distribution of derivative products sector also increases, thus having a positive impact on the welfare of the community around the salt production area. In addition, the successful implementation of clean production in this study is the basis for strengthening the reputation of the salt industry as an industry that is responsible for the environment and society. Thus, the value created is not only economical, but also strengthens social legitimacy and adherence to the principles of sustainable development.

Through the integration of economic, operational, environmental, and social aspects, it can be concluded that the value proposition of the use of bittern waste in the circular economy approach is a holistic and strategic proposition. The success of transforming waste into a source of economic value in this study proves that innovation based on resource use efficiency is able to encourage industrial sustainability while increasing economic acceptance of business actors. These results confirm that the implementation of clean production is not only a response to the need for waste reduction, but is a transformational step to improve the financial performance, productivity, and competitiveness of the salt industry in the long term. Therefore, business models with value propositions like this are worthy of being recommended to be developed on a larger scale as part of the strategic implementation of the circular economy in the national salt industry sector.

Managerial and Industry Implications

The utilization of bittern waste through a circular economy approach offers significant economic value, as waste that was previously a burden can be converted into value-added raw materials such as magnesium and other derivative products. This concept is in line with the finding that mineral recovery from bittern is able to increase revenues and reduce waste disposal costs in the salt industry (Bagastyo et al. 2021). In addition, integrating clean production into the bittern processing stream improves operational efficiency by reducing secondary waste and optimizing energy use. The study confirms that the technology of using bittern waste can produce a high rate of product recovery with a lower environmental impact than conventional processes (Pan et al. 2023).

From a business strategy perspective, the implementation of the circular economy helps increase the competitiveness of the salt industry because it is able to create a new value chain from waste and strengthen the resilience of the raw material supply. The literature shows that waste valorization is a key element for the success of business transformation towards a circular economy (Wildeboer & Savini, 2022). The project's value proposition also includes environmental and social benefits, such as reduced pollution of coastal waters as well as increased employment opportunities in the waste treatment sector. This is consistent with scientific evidence that circular economy models are able to promote sustainability through improved resource efficiency and reduced ecological impact (Yu et al. 2017).

Research Limitations

The limitations in this study are mainly related to the characteristics of the data and the scope of analysis, which is still at the stage of estimation based on business planning. The net cash flow calculations in this study were compiled without the support of full-

scale industrial validation, so potential deviations between actual technical and economic performance with model estimates are still possible. In addition, financial analysis has not fully taken into account the market volatility of processed bittern products, such as magnesium or its derivative compounds, which in practice are strongly influenced by global supply-demand dynamics as well as changes in mineral trading policies. The assumption of the discount rate used is also still static, while macroeconomic conditions can fluctuate that affect the value of investment eligibility, especially related to the sensitivity of IRR and NPV to capital costs. Furthermore, this study has not quantified the social benefits in a measurable way, such as the creation of new jobs, an increase in the income of coastal communities, and a reduction in environmental burden due to liquid waste disposal. Thus, in interpreting the results, it is important to consider that the findings are indicative and require further studies in the form of industrial-scale tests, sensitivity analysis to market parameters, and integration of socio-environmental valuations in order to produce a more comprehensive and representative picture of project feasibility for implementation nationally.

Based on the results of the research that has been conducted, it can be concluded that the use of bittern waste can not only reduce environmental burden but also present new economic opportunities for the salt industry sector. Within the framework of the circular economy**,** the transformation of waste into commercial products plays an important role in optimizing previously worthless resources, efficient production processes, increasing added value along the salt supply chain, and creating jobs and supporting the economies of coastal communities. With a profit margin of more than 70% of total revenue**,** this project shows thatthe clean production approach is able to significantly increase business value despite the low initial investment and operations.

In terms of industry and policy implications, this project provides a practical framework for salt industry players to implement a more environmentally friendly and sustainable business model. Government policies that support clean technology and the circular economy will accelerate the transformation of the local and national salt sector towards higher competitiveness. This is also in line with the literature that emphasizes that economic, environmental and social integration is a prerequisite for long-term sustainability.

These findings indicate that bittern processing as an environmentally friendly business model is not only financially feasible but also strategic to increase the competitiveness of the national salt industry. Projects have the potential for long-term economic sustainability because their profitability does not rest on the exploitation of new resources, but on optimizing the flow of existing production waste.

However, this study has limitations that need to be acknowledged. Some income and cost assumptions are still estimates and have not been tested on a full scale, and the market price volatility of processed waste products needs to be monitored in further research. In addition, although environmental aspects have been quantitatively taken into account, quantitative analysis of socio-environmental impacts has not been conducted in depth, which could be the next direction of research.

CONCLUSION AND RECOMMENDATIONS

Conclusions

This study concludes that the use of bittern waste as an alternative raw material to produce value-added products through clean production technology has proven to be financially and strategically feasible. The results of the business feasibility analysis show that investment indicators such as NPV, IRR, BCR, and Payback Period are positive and meet the investment feasibility criteria, so that the project has high profit prospects and relatively low financial risks. The application of a circular economy approach in the salt industry also contributes to increasing process efficiency, reducing liquid waste, and optimizing value chains that have not been utilized so far. In addition, the use of bittern strengthens industrial sustainability through increasing competitiveness, product diversification, and contributing to economic, social, and environmental aspects simultaneously. Overall, the integration of the use of bittern waste in the production system of the salt industry not only provides significant economic benefits but also supports the transformation towards greener, more innovative, and sustainable industrial models in the future.

Recommendation

Based on the findings of the research, a number of recommendations were given as considerations for the

development of project implementation. For industry players and investors, it is necessary to validate the industry scale and strengthen market management strategies to ensure the stability of demand for bittern derivative products in the long term. The government is expected to provide regulatory support in the form of fiscal incentives, technology assistance, and product quality standardization to accelerate the adoption of clean production technology in the waste treatment sector. In addition, further research is recommended to examine the analysis of sensitivity, volatility of mineral commodity prices, and quantitative valuation of environmental benefits, so that the calculation of BCR can reflect the overall economic and social value produced. No less important, collaborative partnerships among academics, industry, and MSMEs need to be strengthened to increase innovation capacity and expand the downstream of circular-economy products in the national salt sector.

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