GENERATE

Participatory Community Action

Vol 02 (1) 2026 p. 31-39

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Received: 9 July 2026;
Accepted: 15 August 2026;
Published: 18 August 2026.

Conflict of interest statement:
Author(s) reported no conflict of interest

DOI: http://doi.org/10.70764/gdpu-pca.2026.2(1)-5

ENERGY SUBSTITUTION AND EFFICIENCY IMPROVEMENT IN ANCHOVY PROCESSING USING THE BRICHOVY LPG STOVE

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ABSTRACT

Objective: This study aims to present an academic review and technical analysis of the "Brichovy" LPG-fueled industrial boiling stove as a solution for modernizing the anchovy boiling process in Lampung Province. This study focuses on evaluating energy efficiency, fuel consumption, structural reliability, environmental performance, and the feasibility of implementing this technology as a means to improve productivity and sustainability in the anchovy processing industry.

Design & Methods: The study was conducted using an engineering analysis approach that included field observations, secondary data collection, conceptual design studies, structural simulations using Finite Element Analysis (FEA), thermal performance analysis based on heat balance, and theoretical analysis of emission characteristics. Structural analysis was performed under a load of 1,200 N to evaluate stress distribution, deformation, and safety factors, while thermal analysis was used to compare energy efficiency and fuel consumption between the LPG system and traditional wood-burning stoves. Environmental analysis was conducted by comparing PM2.5 and CO emissions based on internationally standardized literature data.

Result: The analysis results show that the LPG-fueled boiling system is significantly more efficient (thermal efficiency of 35.15%) than a traditional wood-fired stove (17.57%). For a single boiling cycle of 100 kg of fish, LPG consumption is estimated at approximately 5 kg, while firewood consumption reaches ±31.39 kg. Structural analysis using Finite Element Analysis (FEA) indicates that the stove's mechanical design has an excellent safety margin, with a safety factor of approximately 3 for the upper frame (SUS 304) and 42.5 for the lower frame (AISI 1035), indicating high structural capacity. From an environmental perspective, LPG demonstrates the cleanest emissions performance, with the potential to reduce PM2.5 emissions by up to several hundredfold (approximately 200–580 times) compared to firewood, creating a healthier work environment. Based on the integrated analysis, this industrial boiling stove is deemed feasible and relevant as an appropriate technology for the anchovy processing industry, with an estimated service life of 10–15 years that supports both technical and economic sustainability.

Keywords: Gas stove; Anchovies; Thermal efficiency; Emissions analysis; Finite element analysis.

INTRODUCTION

PT Pertamina Patra Niaga Regional Sumbagsel, through the Panjang Fuel Terminal in Lampung, is part of PT Pertamina (Persero)'s Commercial & Trading subholding, which plays a strategic role in ensuring the availability and distribution of energy, particularly petroleum products (BBM) and Liquefied Petroleum Gas (LPG) in the Province of Lampung and surrounding areas. In addition to carrying out its operational functions as a national energy provider, the company is also committed to implementing Social and Environmental Responsibility (TJSL) programs focused on community empowerment, improving economic well-being, and developing businesses based on local potential. One of the key focuses of the CSR programs developed is strengthening the capacity of micro, small, and medium-sized enterprises (MSMEs) through the application of appropriate technologies capable of enhancing productivity, efficiency, and business sustainability (Nuriyatman et al., 2025).

PT Pertamina Patra Niaga Regional is committed to supporting the development of MSMEs and a sustainable fisheries processing industry in Lampung Province. One sector of particular focus is the anchovy processing industry, which is spread across coastal areas, particularly in South Lampung and East Lampung Regencies (Ermawati & Marsikha, 2023). This industry plays a strategic role in supporting the economy of coastal communities because it absorbs local labor and produces high-value fishery products. However, most business operators still use traditional production technologies, particularly in the anchovy boiling process, which relies on firewood as the primary energy source. This dependence is widespread among the small and medium-scale processing units concentrated along the South and East Lampung coastline (Ermawati & Marsikha, 2023), underscoring the scale of the problem and the urgency of introducing a more efficient and safer boiling technology for this sector.

The use of firewood in the boiling process has been practiced for generations and is considered an easy-to-implement method. However, this system causes various problems that impact productivity, product quality, operational cost efficiency, and business sustainability (Satriananda et al., 2025). Based on the needs assessment provided by PT Pertamina Patra Niaga Lampung, the main problem faced is low energy efficiency in the boiling process. Wood-fired stoves typically feature an open combustion chamber design, which leads to heat loss through convection and radiation. This results in longer boiling times, higher fuel consumption, and increased production costs. Additionally, fluctuations in the availability and price of firewood, particularly during the rainy season often disrupt the production process and reduce the business's competitiveness.

The next issue relates to product quality and hygiene. Temperature control in wood-fired stoves is relatively difficult to achieve, resulting in an uneven boiling process (Yanuar et al., 2024). This temperature inconsistency affects the quality of the anchovies produced, including their texture, taste, color, and shelf life. As a result, the products often have inconsistent quality and may fail to meet the national quality standards as stipulated in SNI 8273:2016 regarding dried anchovies. On the other hand, the use of boiling equipment that does not meet food-grade safety standards and is prone to corrosion can also increase the risk of product contamination, thereby reducing food quality and safety (Jiastuti, 2018).

In addition to product efficiency and quality, occupational health and safety (OHS) is also a major concern. The wood-burning process produces thick smoke containing fine particulate matter (PM2.5) and hazardous gases such as carbon monoxide (CO). Continuous exposure to these pollutants can cause respiratory health problems among workers (Sidebang et al., 2025). A hot, stuffy, and smoke-filled work environment also has the potential to reduce workers' comfort, concentration, and productivity (Saputra & Rahmawati, 2025). Therefore, a technological innovation is needed that not only improves production efficiency but also creates a safer and healthier work environment.

In response to these issues, this community service project offers a solution in the form of a study and implementation of the "Brichovy" industrial boiling stove technology, which uses Liquefied Petroleum Gas (LPG) as an alternative to wood-burning stoves. The use of LPG in industrial burner systems is expected to improve thermal efficiency through more stable and controlled combustion, thereby shortening boiling times and making energy consumption more efficient. Additionally, the use of a cleaner energy source allows for a reduction in smoke emissions and hazardous pollutants in the work environment.

Brichovy's industrial boiling stove is also designed using food-grade SUS 304 stainless steel for the boiling pot, thereby enhancing the hygiene of the processing and maintaining product quality. From an engineering perspective, the stove's structure is analyzed using technical simulation methods to ensure it can safely and reliably withstand operational loads. Meanwhile, from an occupational safety and health (OSH) perspective, the use of LPG can significantly reduce exposure to smoke, PM2.5 particulates, and carbon monoxide, which have long been major risks for workers (Zahara et al., 2025). Thus, the implementation of this technology not only contributes to increased productivity and product quality but also supports the creation of a safer, more efficient, and more sustainable production process for the anchovy processing industry in Lampung Province.

Therefore, this study aims to evaluate the technical feasibility, thermal efficiency, structural safety, and environmental performance of the Brichovy LPG stove relative to the conventional wood-fired boiling system, in order to determine its suitability as an appropriate technology for improving productivity, product quality, occupational safety, and sustainability in the MSME-scale anchovy processing industry in Lampung Province.

METHODS

This community service activity was carried out through a collaboration between the implementation team and PT Pertamina Patra Niaga's Sumbagsel Regional Fuel Terminal in Panjang, Lampung, as a supporting partner for the community empowerment program. The activity focused on a technical study of the application of the "Brichovy" industrial Liquefied Petroleum Gas (LPG)-fueled cooking stove as an alternative technology in the anchovy processing. The approach used was an engineering approach that integrated theoretical analysis, numerical simulation, and technology performance evaluation (Zulfadlillah, 2024). This method was chosen to provide a comprehensive overview of the technical feasibility, energy efficiency, structural safety, and environmental impact of using LPG stoves compared to conventional wood-fired boiling systems.

The implementation of this study consists of four main stages: (1) literature review and conceptual design analysis, (2) simulation and structural analysis, (3) thermal performance and energy efficiency analysis, and (4) analysis of emission characteristics and environmental impacts. Each stage is interrelated, resulting in technical recommendations that can serve as a basis for the application of appropriate technology in the anchovy processing industry.

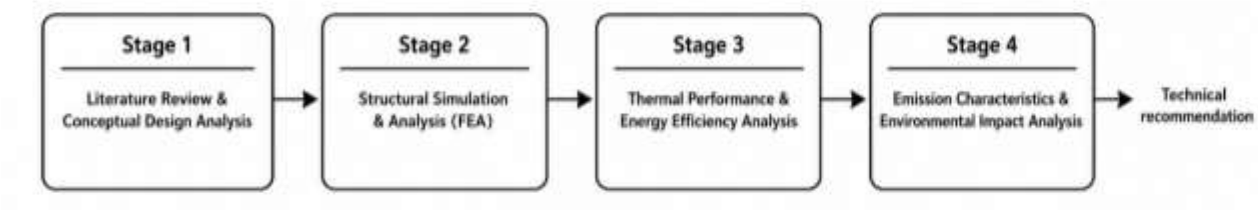

Figure 1. Research flowchart showing the four sequential stages of the engineering analysis approach used in this study.

1. Literature Review and Conceptual Design Analysis

The first stage began with a systematic literature review of various scientific references related to fishing product boiling technology, the combustion characteristics of wood and LPG, heat transfer, energy efficiency, workplace safety, and quality standards for fishery products. The literature was sourced from reputable scientific articles, reference books, national and international standards, and relevant technical documents (Rizkina et al., 2025). This review aimed to establish a scientific basis for determining the technical specifications of a stove capable of meeting the operational needs of the anchovy processing industry.

Next, a conceptual design analysis of the "Brichovy" industrial boiling stove was conducted. The analysis covered material selection, combustion chamber configuration, the combustion system (burner), heat distribution mechanisms, construction dimensions, as well as ergonomic and operational ease aspects. SUS 304 stainless steel was selected for parts in direct contact with the product because it offers high corrosion resistance, is easy to clean, and meets food-grade requirements. Additionally, the thermal insulation system was designed to minimize heat loss during the boiling process, while the frame construction was adapted to safely support operational loads.

2. Structural Simulation and Analysis

The second stage aims to evaluate the strength and reliability of the stove structure before implementation. The analysis was conducted using the Finite Element Analysis (FEA) method via three-dimensional engineering simulation software (Elmiawan et al., 2022). This simulation allows for the analysis of stress distribution, strain, deformation, and safety factors without the need for destructive testing of the prototype.

The stove's geometric model was created according to the actual design, and the material's mechanical properties were assigned based on the standards for the materials used: SUS 304 stainless steel for the main components and AISI 1035 carbon steel for the support frame. A static load of 1,200 N, equivalent to approximately 120 kg was applied to the pot support area to represent maximum operating conditions. The boundary conditions were adjusted to match the stove's actual position during use. The simulation results including von Mises stress distribution, maximum deformation, and safety factor values, were analyzed to ensure that all components remain within the material's yield strength limits, thereby ensuring the stove can be operated safely and has a long service life.

3. Thermal Performance and Energy Efficiency Analysis

The third stage was conducted to evaluate the thermal performance of the Brichovy stove compared to a traditional wood-fired cooking system. The analysis used a thermodynamic approach via the heat balance method, taking into account all energy flows entering and leaving the system (Nurfajrina et al., 2025). Calculations were performed for the boiling process of 100 kg of anchovies as a single production cycle. Useful energy (Q_{useful}) was calculated based on the heating requirements for water, fish, and supporting components until the operating temperature was reached. Next, energy loss (Q_{loss}) was calculated, which resulted from heat transfer via convection and radiation, as well as energy carried away by the exhaust gases. Total energy input (Q_{input}) was determined based on the calorific values of each fuel, namely LPG and firewood.

The system's thermal efficiency is calculated using the ratio of useful energy to total energy input. Additionally, fuel consumption is estimated for each production cycle to calculate the potential for energy savings and reduced operating costs if the wood-fired boiling system is replaced with a Brichovy LPG stove. This analysis is also used to evaluate the stove's ability to produce a more stable temperature distribution, thereby supporting improved product quality.

4. Analysis of Emission Characteristics and Environmental Impacts

The final stage focuses on evaluating the environmental impacts of using LPG stove technology. The analysis was conducted through a comparative study based on secondary data obtained from various scientific publications, international standards, and previous research findings on the emission characteristics of biomass and LPG combustion (Rezeki et al., 2024). The parameters analyzed include fine particulate matter (PM2.5), carbon monoxide (CO), and carbon dioxide (CO_2), which are key indicators of combustion process quality and its impact on health and the environment. Emission data were compared based on the unit of energy produced, enabling an objective evaluation between the two types of fuel.

A descriptive analysis was then conducted on the potential for emission reductions, improvements in workplace air quality, and reductions in health risks to workers due to exposure to combustion fumes. In addition to occupational health and safety aspects, the evaluation also considered the contribution of LPG use to cleaner production practices, energy efficiency, and the reduction of environmental impacts. The results of the analysis serve as the basis for assessing the feasibility of implementing the Brichovy stove as an appropriate technology that supports the sustainability of the anchovy processing industry in Lampung Province.

RESULT

The community service activities were carried out in stages using an engineering approach that included identifying partner needs, designing technology, conducting technical simulations, analyzing performance, and evaluating environmental impacts. All stages were designed to produce technological solutions that not only improve the efficiency of the anchovy boiling process but also address workplace safety, operational sustainability, and the reduction of environmental impacts. The results show that the "Brichovy" LPG-fueled industrial boiling stove outperforms the conventional wood-fired boiling system that has long been used by our partners. The results of the project are outlined as follows.

1. Literature Review and Conceptual Design Analysis

The initial phase of the project began with a literature review to identify developments in industrial stove technology, the characteristics of LPG combustion systems, the principles of heat transfer, energy efficiency, and safety and emissions aspects in the processing of fishery products. A literature review was also conducted on various studies regarding the modernization of fish processing technology, thereby providing a scientific basis for developing technical specifications for stoves tailored to the needs of the SME-scale anchovy processing industry. The results of the literature review indicate that the use of LPG-fueled stoves with a closed combustion system has the potential to increase thermal efficiency, reduce energy consumption, and produce significantly lower emissions compared to traditional wood-fired stoves (Budhiati, 2018; Ismail & Amir, 2025).

Next, the community service activities continued with a field visit to the site of an anchovy processing industry partner in Lampung Province. This activity aimed to gain a firsthand understanding of the production process, particularly the anchovy boiling stage, which still relies on wood-fired stoves. Observations revealed that the partner still relies on a conventional boiling system featuring a simple stove design and an open combustion chamber. In addition to conducting field observations, the team also held discussions with business operators to identify various challenges they face, including high fuel consumption, lengthy boiling times, inconsistent product quality, and working conditions filled with combustion smoke. This information served as the basis for designing technological solutions tailored to the partners' needs.

Following the initial identification process, secondary data was collected and direct measurements were taken of the existing stoves used by our partners. The measurements included the dimensions of the firebox, boiling capacity, types of materials used, combustion chamber configuration, and other operational characteristics. This data served as the basis for a comparative analysis with the design of the "Brichovy" industrial boiling stove. The measurement results indicated that the boiling system currently in use does not yet incorporate the principles of energy efficiency and optimal heat control, potentially leading to high energy losses during the production process.

2. Structural Simulation and Analysis

Based on the results of needs assessment, literature review, and field measurements, the team successfully developed a technical design for the "Brichovy" industrial boiling stove, which is designed to improve efficiency, safety, and operational reliability (Itera, 2026). The stove's design integrates principles of heat transfer engineering, structural load distribution, ease of maintenance, and ergonomics to support a more effective boiling process. SUS 304 stainless steel was selected for parts in direct contact with the product to meet standards for hygiene, corrosion resistance, and food safety, while the support frame uses a material with high mechanical strength to optimally support operational loads.

The structural reliability was then evaluated using Finite Element Analysis (FEA) simulations. Simulation results for the upper frame, which used SUS 304 material and was subjected to a load of 1,200 N, showed a maximum stress of 68.8 MPa with a Safety Factor (SF) of approximately 3.03. This value indicates that the working stress is still well below the material's yield strength, so the structure is deemed safe for use under maximum operational conditions. Meanwhile, the simulation of the lower frame, which uses AISI 1035 material, yielded a maximum stress of 6.65 MPa with a Safety Factor of approximately 42.5. This very high safety factor indicates that the support structure has excellent capacity to withstand operational loads. Overall, the simulation results indicate that the Brichovy stove design offers a high level of safety and reliability for long-term use in the anchovy processing industry.

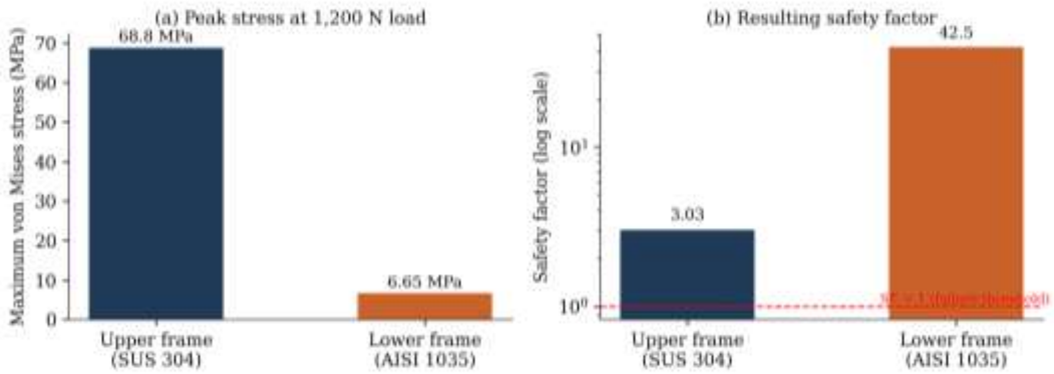

Figure 2. FEA results for the Brichovy stove frame under a static load of 1,200 N: (a) maximum von Mises stress and (b) resulting safety factor for the upper (SUS 304) and lower (AISI 1035) frames.

These results are consistent with, and further corroborated by, recent FEA studies on similar food-grade stainless-steel equipment. Siswadi et al. (2025), analyzing a stainless steel 304 rotary steak-grilling machine under a comparable static load, reported a maximum stress of 58.60 MPa and a factor of safety of 3.5 — closely comparable in magnitude to the SF ≈ 3.03 obtained for the Brichovy upper frame, suggesting that both designs sit within a similar, literature-consistent safety margin for food-processing equipment rather than being unusually over- or under-designed. Similarly, Tanriver et al., (2025) reported a safety factor of 8.39 for a stainless-steel chimney-clamp assembly under a much larger applied force, showing that safety factors in the tens (as observed for the Brichovy lower frame, SF ≈ 42.5) are not unusual for support components that are not the primary load-bearing element of a structure. From an engineering-optimization standpoint, the very high SF of the lower frame also indicates room to reduce material thickness or substitute a lighter-gauge section in future design iterations, which could lower fabrication cost without compromising safety — a practical recommendation for scaling up production of the Brichovy stove for other MSME partners.

3. Thermal Performance and Energy Efficiency Analysis

A thermal performance analysis was conducted to evaluate the Brichovy stove's ability to utilize combustion energy more effectively than conventional systems. Calculations were performed using an energy balance approach, taking into account the heat requirements during the boiling process, the energy absorbed by the product, and the energy generated from fuel combustion (Nurfajrina et al., 2025). This analysis aims to determine the system's thermal efficiency while providing an overview of the potential energy savings that can be achieved if this new technology is applied to the anchovy processing industry.

The results of the thermodynamic calculations show that the boiling process for 100 kg of anchovies requires useful energy (Q_{useful}) of 82,754 kJ. In the Brichovy LPG stove system, the total input energy (Q_{in}) required is 235,443 kJ, with a theoretical thermal efficiency of 35.15% and fuel consumption of approximately 5 kg of LPG.

By comparison, a traditional wood-fired stove system achieves only 17.57% thermal efficiency, requiring approximately 31.39 kg of wood to produce the same amount of energy. These results show that LPG is nearly twice as efficient as firewood. This increase in efficiency directly leads to lower energy consumption, reduced operating costs, and improved productivity in the boiling process. In addition, the LPG combustion system also provides more stable temperature control, which has the potential to produce more consistent product quality.

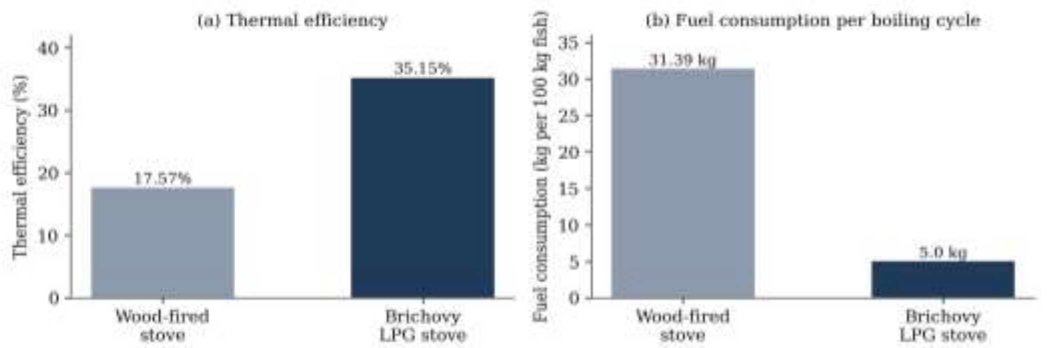

Figure 3. Comparison of (a) thermal efficiency and (b) fuel consumption between the wood-fired stove and the Brichovy LPG stove, per 100 kg boiling cycle

The 35.15% thermal efficiency obtained for the Brichovy stove is close to the 34.45% efficiency reported by Rathore et al. (2022) for a three-pot improved cookstove, and it sits within the range summarized by Deng et al., (2023) in their review of factors affecting the thermal efficiency of household biomass and LPG cookstoves. This agreement across independent studies lends credibility to the calculated value. At the same time, the review by Deng et al., (2023) also reports that advanced forced-draft and gasifier-type designs can reach thermal efficiencies in the 40–53% range, indicating that further gains — for example, through improved combustion-chamber insulation or secondary-air control — remain possible for future iterations of the Brichovy stove. Nonetheless, nearly doubling thermal efficiency relative to the partner's existing wood-fired stove, together with an 84% reduction in fuel mass per cycle, represents a substantial and immediately actionable improvement for the partner MSME, translating directly into lower fuel cost and shorter boiling time, and supporting more stable temperature control that can improve the consistency of product quality.

4. Analysis of Emission Characteristics and Environmental Impacts

In addition to improving energy efficiency, the use of the Brichovy stove was also evaluated from an environmental perspective through an analysis of combustion emission characteristics. This evaluation is important because the process of boiling fish using firewood generally produces high levels of smoke, fine particulate matter, and toxic gases that can impact workers' health and the quality of the surrounding environment. Therefore, the use of LPG is expected to serve as a cleaner fuel alternative and support the implementation of sustainable production processes.

The analysis of emission characteristics was conducted based on comparative data from various studies and international testing standards (Rezeki et al., 2024). The results of the analysis show that LPG combustion produces significantly lower emissions compared to traditional wood burning. For fine particulate matter (PM2.5), LPG emissions range only from 2.39 to 4.39 mg/MJ of energy produced, whereas traditional wood burning can reach approximately 1,380 mg/MJ. This highly significant difference indicates that the use of LPG can substantially reduce air pollution in the workplace.

In addition, carbon monoxide (CO) emission rates in LPG systems were recorded as very low, less than 1.5 g/hour while wood combustion produces significantly higher CO emissions due to incomplete combustion. These results confirm that replacing wood fuel with LPG has great potential for creating a healthier, safer, and more comfortable work environment for workers. The reduction in particulate and toxic gas emissions also supports efforts to implement more environmentally friendly and sustainable production processes in the anchovy processing industry.

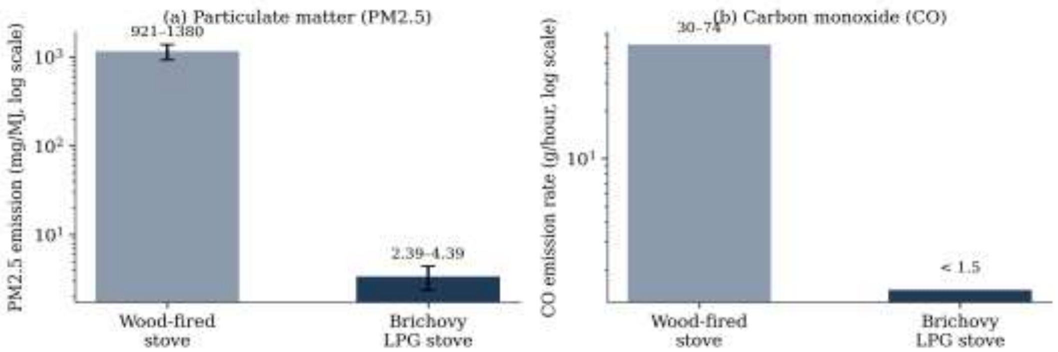

Figure 4. Comparative emission characteristics of the wood-fired stove and the Brichovy LPG stove, based on secondary literature data (log-scaled axes; wood-fired ranges shown as reported).

Table 1 summarizes the overall achievements of the activity across all four analysis stages, comparing the previous (wood-fired) condition with the condition after adopting the Brichovy gas stove.

Table 1. Achievements in Activity Implementation

No	Achievement Indicators	Previous Conditions (using firewood)	After (using a gas stove)	Improvements/Enhancements
1	System thermal efficiency	17.57%	35.15%	A 99.9% increase in efficiency (nearly double)
2	Fuel consumption (per 100 kg of fish)	31.39 kg of firewood	~ 5 kg of LPG	An 84% reduction in fuel mass. LPG is 6.3 times more efficient in terms of mass
3	PM2.5 particulate emissions (per unit of energy)	~921–1,380 mg/MJ	~2.39–4.39 mg/MJ	Potential to reduce harmful particulate emissions by up to several hundredfold (approximately 200–580×)

No	Achievement Indicators	Previous Conditions (using firewood)	After (using a gas stove)	Improvements/Enhancements
4	CO emission rate (toxic gas)	~30–74 g/hour	< 1.5 g/hour	Potential for a drastic reduction in toxic gas exposure, improving occupational health
5	Structural reliability and safety	undefined, simple and non-standard structure	safety factor > 3 (very safe)	Guaranteed improvement in operational safety through design engineering
6	Estimated equipment service life	short, dependent on maintenance and makeshift materials	10 - 15 years	Improved sustainability of production equipment investment
7	Process control and quality consistency	Low, fluctuating temperature	high, stable and easily adjustable temperature	Potential for improved quality consistency of anchovy products

The implementation of this project demonstrated significant improvements in various technical and operational aspects of the anchovy boiling process. Thermal efficiency nearly doubled, rising from 17.57% to 35.15%, accompanied by an 84% reduction in fuel consumption through the more efficient use of LPG compared to firewood. Additionally, there was a drastic reduction in particulate matter and CO emissions, resulting in a healthier work environment. From an engineering perspective, the newly developed stove offers a higher level of safety with a safety factor above 3, a longer service life, and the ability to maintain stable temperatures, thereby improving the consistency of anchovy product quality and supporting the sustainability of the production process.

These results should nonetheless be interpreted with several limitations in mind. The thermal-efficiency and fuel-consumption figures were derived analytically from a heat-balance calculation rather than from repeated, instrumented field trials, so the reported values represent theoretical rather than empirically validated performance under actual MSME operating conditions. Likewise, the emission comparison relies on secondary literature data for both LPG and firewood combustion rather than on-site PM2.5 and CO measurements at the partner's facility, which means the magnitude of improvement, though consistent with published ranges, may differ once local fuel quality, stove operating practice, and ventilation conditions are accounted for. Similarly, the structural safety factors were obtained from a static FEA simulation under a single representative load case rather than cyclic or fatigue loading that better reflects repeated daily use. Future work involving direct field measurement of thermal efficiency, emissions, and structural performance over an extended operating period would strengthen confidence in these findings and is recommended before wider dissemination of the technology.

CONCLUSION

A community service project conducted through an engineering approach has successfully evaluated the feasibility of implementing the "Brichovy" LPG-fueled industrial boiling stove as a solution for modernizing the anchovy boiling process in MSME-scale processing industries in Lampung Province. The evaluation was conducted comprehensively through theoretical studies, structural simulations, thermal performance analysis, and emission characteristic analysis, thereby providing a comprehensive overview of the advantages of the proposed technology compared to conventional wood-fired boiling systems.

The results of the literature review and conceptual design analysis indicate that the "Brichovy" LPG-fueled industrial boiling stove technology has greater potential than traditional wood-fired stoves in supporting the anchovy processing process. The stove's design, which utilizes food-grade SUS 304 stainless steel, a more controlled combustion system, and a construction tailored to industrial needs is capable of improving hygiene, ease of operation, and the quality of the boiling process.

The results of structural simulations using the Finite Element Analysis (FEA) method show that the stove design has a high level of safety and reliability. The safety factor values for all major components are above the safe limit, meaning the structure can withstand operational loads without experiencing mechanical failure. These findings indicate that the Brichovy stove is suitable for use as safe production equipment with a long service life.

Thermal performance analysis confirms that substituting wood fuel with LPG increases thermal efficiency from 17.57% to 35.15%, nearly doubling it. This improvement is accompanied by a reduction in fuel consumption of approximately 84%, thereby offering potential energy savings, lower operating costs, and more stable boiling temperatures to ensure consistent anchovy quality.

From an environmental perspective, the use of Brichovy stoves produces significantly lower emissions of particulate matter (PM2.5) and carbon monoxide (CO) compared to traditional wood-burning systems. This has the potential to improve air quality in the workplace, reduce the risk of health problems among workers, and support the adoption of cleaner and more sustainable production processes. Overall, the implementation of the Brichovy stove improves energy efficiency, operational safety, product quality, and sustainability in the anchovy processing industry, making it a suitable technology to recommend for small and medium-sized enterprises (SMEs) in the fisheries processing sector.

Beyond its practical contribution, this study offers a theoretical contribution by demonstrating, through an integrated heat-balance, structural, and emission-based framework, how appropriate-technology interventions for MSME-scale food processing can be evaluated jointly across thermal efficiency, structural safety, and environmental performance rather than each in isolation. This integrated evaluation framework may be adapted to assess other fuel-substitution interventions in small-scale food and agro-processing industries facing similar energy, safety, and environmental trade-offs. Future research is recommended to (1) validate the theoretical thermal-efficiency and emission estimates through direct, instrumented field measurement at partner sites; (2) assess the economic feasibility of the Brichovy stove, including payback period and total cost of ownership relative to firewood-based operations; (3) evaluate structural performance under cyclic and long-term operational loading rather than a single static case; and (4) examine the broader social and occupational health outcomes of technology adoption among anchovy-processing workers over an extended period.

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