SALAGA Journal
Vol. 03, No. 02, December 2025, pp. 83~91
ISSN: 3032-2677
DOI: 10.70124/salaga.v3i2.1851

Economical Used-Oil Stove for Post-harvest Energy in Agriculture

Muhamad Khuldi Mamangkai*[1], Hendro Maxwell Sumual[1], and Jenly Dyliep Isria Manongko[1]
[1]Faculty of Engineering, Universitas Negeri Manado, Tondano, Indonesia

Article Info

Article history:

Received 05 30, 2025
Revised 06 17, 2025
Accepted 11 16, 2025

Key words:

Alternative energy
Smallholder farming
Thermal efficiency
Used oil stove

ABSTRACT

This study aims to develop and test the performance of energy-efficient stoves fueled by used oil as a renewable alternative energy solution for small-scale farmers. The stoves are designed to reduce dependence on subsidized Liquefied Petroleum Gas (LPG) while utilizing the increasing amount of oil waste in rural areas. The method used is Research and Development (R&D) with performance testing through the Water Boiling Test (WBT) and Fuel Consumption Rate (FCR) calculations. The main findings show that used oil stoves have an average thermal efficiency of 32.28%, meeting the SNI 7926:2013 standard (>30%), although slightly below the efficiency of LPG stoves (37.45%). These stoves are able to boil water 3-5 minutes faster than LPG stoves after reaching stable combustion conditions. From an economic perspective, the daily operating cost of used oil stoves is only Rp1,986, or 69.45% cheaper than LPG, and only consumes 4.9% of farmers' monthly income—far lower than LPG, which reaches 16%. With a production cost of IDR 363,000 per unit, this stove is not only affordable but also has the potential to reduce environmental impact through the utilization of waste oil. The research results indicate that used oil stoves are suitable for implementation as appropriate technology that supports energy security and the household economy of farmers.

Corresponding Author:

Muhamad Khuldi Mamangkai
Faculty of Engineering, Universitas Negeri Manado
UNIMA Campus in Tondano 95618, Tonsaru, Kec. Tondano Selatan, Minahasa Regency, North Sulawesi
E-mail: khuldimamangkai@gmail.com

1. INTRODUCTION

Energy and waste management are critical issues that directly affect the sustainability of the agricultural sector, particularly in rural areas. In Indonesia, Liquefied Petroleum Gas (LPG) has become the predominant energy source for households, with over 80% of households across various districts and cities relying on it as their primary cooking fuel (BPS-Statistics Indonesia, 2023). This dependence extends to the agricultural sector, where LPG is increasingly being used for activities such as powering irrigation pumps (Rama Pien et al., 2024). In North Sulawesi, this reliance is evident, with the distribution of subsidized 3-kg LPG cylinders reaching 43,798,954 units as of June 8, 2025, thus fulfilling 87.53% of the annual quota (North Sulawesi Provincial Government, 2025). This high level of consumption underscores a strong dependency on fossil fuels, which not only leads to high operational costs but also exposes farmers to significant vulnerabilities, including price volatility and supply chain disruptions, thereby threatening long-term energy security and sectoral sustainability.

Various efforts have been made to find alternative energy sources that support the sustainability of the agricultural sector and reduce dependence on fossil fuels. Some of the innovations that have been developed include the utilization of agricultural waste (Syam et al., 2025), household waste such as cooking oil for biodiesel (Monika et al., 2023), and the use of used oil as an alternative fuel. Used oil from vehicles and agricultural machinery continues to increase as the number of users grows, but most of it is not properly managed and is often disposed of carelessly, polluting the soil and water. In fact, research shows that used oil has high thermal energy content and can be processed into fuel through pyrolysis or controlled combustion. Zahir Hussain et al. (2020) found that used oil processed through pyrolysis can produce diesel fuel with characteristics close to conventional fuel. Al-Omari (2008) reported that mixing used oil with LPG in a furnace increases thermal radiation by up to 80%, while Silaban et al. (2025) proved that used oil can be burned with pollution levels below the threshold. These findings support the potential of used oil as an energy source that can reduce waste and sustainably utilize high-energy materials.

The development of appropriate technology capable of converting waste into energy sources is an important approach in modern agricultural engineering. An innovative solution that can be applied is a stove fueled by used oil. Previous studies have explored the use of waste oil as an alternative fuel, such as Akhyar (2014), who designed a waste oil-fueled metal smelting furnace, and Pratama et al. (2020), who developed a waste oil burner with a pressure of up to 3.5 bar and a combustion temperature of 1,127°C. A recent study by Sudarno et al. (2024) showed that the application of a preheating system can increase the efficiency of used oil stoves by up to 55.5% with a flame temperature of more than 1,000°C. However, most of these studies have focused on the needs of the metal industry or engineering laboratories and have not highlighted aspects of cost efficiency and suitability for farming households. This study offers a new approach by designing an economically used oil stove that is more applicable to the agricultural sector, particularly supporting post-harvest activities and small-scale food processing. With a simple yet effective design, this stove allows the use of used oil without additional materials and achieves sufficient thermal efficiency for cooking or processing agricultural products.

However, the main challenge in using used oil as fuel is ensuring that the combustion process is efficient, stable, and safe at the household scale. Therefore, comprehensive research and testing are required on the performance of the designed stove, including its thermal efficiency, fuel consumption, ignition time, and operational costs. This study aimed to design and test the performance of an economical household-scale stove fueled by used oil using a design and experimental testing approach. Evaluations were conducted using the Water Boiling Test (WBT) method to measure thermal efficiency and the Fuel Consumption Rate (FCR) to determine fuel consumption levels. In addition, this study compares the performance of used oil stoves with LPG gas stoves as a common benchmark in the field. It is hoped that the results of this study will contribute to the development of alternative energy technology that is not only economical and environmentally friendly, but also relevant and applicable in supporting agricultural activities at the household and small-scale levels.

2. MATERIALS AND METHODS

2.1. Tools and Equipment

All the tools and equipment used in the fabrication and performance testing phases of this study are detailed in this section.

The tools employed in the design and fabrication phase included a Shielded Metal Arc Welding (SMAW) electric welding machine for metal joining, an 800-watt hand grinder for cutting and smoothing components, and an electric drill with a 10 mm chuck capacity. The supporting tools comprised a 500-gram steel hammer, 12-inch square ruler, 3-meter measuring tape, pliers, and a marker pen.

For the performance testing and data collection phase, the primary test object was the fabricated used oil stove. The experimental setup for comparison included a conventional single-burner LPG gas stove (Rinnai RI-712T), a standard aluminum cooking pot, a K-type thermocouple for water temperature measurement, a digital scale with 0.01-gram precision for weighing fuel, a stopwatch, and a 1000 ml measuring cup.

2.2. Materials

The materials utilized in this research are categorized based on their application in prototype fabrication and experimental testing.

2.2.1. Fabrication Materials

The prototype stove was constructed using readily available heat-resistant materials. The main structural components consisted of 3.5 x 1.5 cm hollow iron for the frame and a 5-inch diameter iron pipe for the combustion chamber. Supports and fittings were made from socket pipes and a 4 × 4 cm angle iron. The fuel tank body was formed from a 1.5 mm thick iron plate, while the stove stand used a 3 mm thick plate. The fuel system included a ¼-inch brass tap to regulate oil flow and a 12V, 30 W DC mini blower (input: AC 100–240 V 50/60 Hz) to supply combustion air. Consumables for assembly included RB26 welding wire, 4-inch cutting and polishing grinding wheels, and 1.5 mm and 2.5 mm diameter drill bits for creating the combustion nozzle holes.

2.2.2. Testing Materials

The primary fuel for testing was used motorcycle engine oil collected from local workshops. The oil was stored in a sealed container for more than one month and filtered to remove coarse particulates prior to use. Its higher heating value (HHV) was taken as 42,400 kJ/kg based on Patel and Shadangi (2020). For comparative performance analysis, commercially subsidized 3-kg LPG cylinders were used, with an HHV of 46,962 kJ/kg (World Nuclear Association, 2025). The universal heating medium for all tests was 2 liters (approximately 2 kg) of clean water. The values for the specific heat of water (C_p = 4,182 kJ/kg·°C) and latent heat of vaporization (L = 2,256 kJ/kg) were adopted from standard thermodynamic references (Engineering Toolbox, 2025a, 2025b).

2.3 Research Method and Procedure

This study employed a Research and Development (R&D) approach, executed through a structured and iterative cycle. The process began with problem identification and literature review, leading to the conceptual design of the stove. This was followed by the fabrication of the prototype, as described in Section 2.4. The core of the procedure involved rigorous experimental testing to evaluate performance.

2.3.1. Performance Testing Protocol

The stove's performance was evaluated using standard WBT and FCR analyses. Testing was conducted in three consecutive phases: (1) Cold Start, igniting the stove from ambient temperature; (2) Hot Start, reigniting the stove immediately after the first test; and (3) Simmering, maintaining water at boiling temperature. Each test was repeated three times, and the average values were calculated to ensure reliability.

2.3.2. Data Collection Procedure

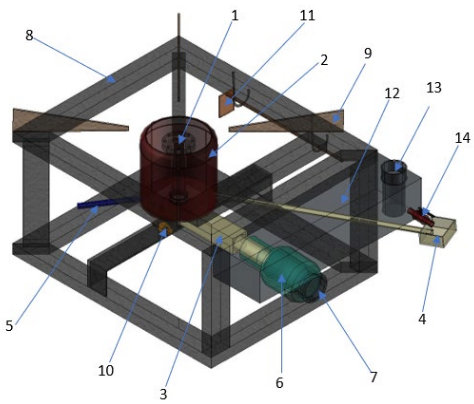
During testing, a 2-liter (±2 kg) of water, measured with a 1000 ml measuring cup and validated by a digital scale, was heated in a standard pot. The water temperature was recorded at the pot's center using a K-type thermocouple. The time taken for water to reach its boiling point (t_1) and the total combustion duration (t_2) were measured using a stopwatch. Fuel consumption for the heating phase (B_1) and the total test (B_2) was determined by weighing the fuel source before and after each test using a digital scale with a precision of 0.01 grams. The power input of the electric blower (P = 0.030 kW) was calculated from its rated voltage and current (12V, 2A) and included in the energy input for the oil stove.

2.3.3. Data Analysis Method

The collected data were analyzed to determine the key performance indicators. The thermal efficiency (η) was calculated separately for the oil stove (incorporating blower power) and LPG stove using standard energy balance formulas. The FCR was calculated by dividing the mass of fuel consumed by the total burning time. Operational costs were derived from the local market prices of fuel and electricity.

2.4 Stove Design

A systematic design process was undertaken to develop a stove that meets the post-harvest energy needs in agricultural environments. The design considers combustion efficiency, ease of use by farmers, and availability of local materials to reduce production costs. The design stages include determining the dimensions of the stove, the layout of the main components (furnace, tank, oil channel, and blower), as depicted in Figure 1, and preliminary testing of the stability of the shape and heat distribution. The design is carried out using AutoCAD software to produce precise technical visualizations prior to the fabrication stage.



Description:

1.	Nozzle	8.	Frame
2.	Combustion Furnace	9.	Stove trivet
3.	Air duct	10.	Connecting bolt / nut
4.	Oil line	11.	Charcoal scoop
5.	Oil drain	12.	Tank
6.	Blower	13.	Oil inlet
7.	Adjustable	14.	Oil tap

Figure 1. Stove Design

2.5 Test Parameters

In this study, several key parameters were used to measure the performance of stoves fueled with used oils. The first parameter was the thermal efficiency, which was measured using the WBT method to determine how much of the heat energy from the fuel was successfully used to heat water. The second parameter is the FCR, which describes the rate of fuel consumption per unit time during the heating process. In addition, the boiling time of water was also measured, which is the duration required for the stove to raise the water temperature from the initial temperature to the boiling point (100°C). The fourth parameter is the daily and monthly operational costs, calculated based on fuel consumption and the unit price of fuel used during testing. Finally, the production cost of the stove was analyzed, which is the total cost of manufacturing one unit of the stove, including all materials and components required in the fabrication process.

2.6 Data Analysis

The test results were analyzed quantitatively using the WBT method and FCR calculations to assess the heat transfer efficiency and fuel consumption rate of the designed stove. This approach is highly relevant in the context of agricultural engineering, particularly in the development of energy-efficient technology to support post-harvest activities, such as boiling and processing agricultural products at the household level of farmers. The WBT method in this study is divided into three testing stages: Cold Start Test, conducted when the stove is turned on in a cold condition; Hot Start Test, conducted after the stove reaches the operating temperature; and Simmering Test, aimed at observing the stove's ability to maintain water boiling for a certain period. Each testing stage provided important information regarding the thermal characteristics and actual performance of the stove during everyday use.

In this study, the thermal efficiency was calculated using two formula models based on the characteristics of each stove:

2.6.1 Thermal Efficiency of Oil Stoves (with Blower):

Oil stoves use a mini electric blower to supply air. Therefore, the power consumption of the blower was also included in the total energy input.

$$\eta = \frac{m \cdot c \cdot \Delta T}{m_f \cdot HHV + P_{\text{blower}} \cdot t} \times 100\% \quad (1)$$

where *m* is the mass of water (kg), c is the specific heat of water (4,182 kJ/kg·°C), *ΔT* is the change in water temperature (°C), *mf* is the mass of fuel (kg), *HHV* is the higher heating value of the fuel (kJ/kg), P_{blower} is the blower power, and t is the time taken to boil the water.

2.6.2 Thermal Efficiency of LPG Gas Stoves (without blower):

LPG gas stoves do not use a blower; therefore, the calculation only considers the energy from the gas fuel.

$$\eta = \frac{m \cdot c \cdot \Delta T}{m_f \cdot \text{HHV}} \times 100\% \quad (2)$$

where *m* is the mass of water (kg), c is the specific heat of water (4, 182 kJ/kg·°C), *ΔT* is the change in water temperature (°C), *mf* is the mass of fuel (kg), and *HHV* is the higher heating value of the fuel (kJ/kg).

2.6.3 Fuel Consumption Rate (FCR)

The FCR is used to measure the rate of fuel consumption during the heating process.

$$\text{FCR} = \frac{m_f}{t} \quad (3)$$

where mf is the mass of fuel used in kilograms, and *t* is the heating time in minutes or seconds. The FCR value is used to calculate fuel usage and can be compared between different types of fuel or combustion systems.

3. RESULTS AND DISCUSSION

3.1 Stove Fabrication Results

A prototype stove fueled by used oil was successfully fabricated (Figure 2) using lightweight metal materials and supporting components commonly found in rural areas. The main structure consists of a hollow iron frame and iron pipes, with a 5-inch diameter combustion chamber and a 12 V 30 W electric blower for air supply; the detailed components are listed in Table 1. All components are designed to support efficient and stable oil combustion and can be operated by farmers without requiring high technical skills.

Figure 2: Stove Fabrication Results

Table 1. Specifications of oil stove fabrication.

No.	Component Name	Description
1.	Stove Frame	Holo iron 3.5x1.5 cm / 4x4 cm angle iron
2.	Stove Placemat	Iron Plate 4 mm
3.	Combustion Furnace	Iron Pipe 5 Inch
4.	Nozzel	Iron Pipe ½ Inch / 2 Inch
5.	Wind Channel	Iron Holo 3.5x3.5 / Iron Pipe ½ Inch
6.	Oil Channel	3cm *Stainless* Pipe
7.	Fuel Tank	Iron Plate, Dimension L36xp10xt8 cm
8.	Charcoal Scoop	Iron 5mm / Iron Plate 3x2 cm
9.	Blower	Input Ac 100-240V 50/60Hz. Output Dc 12V 2A
10.	Oil Tap	Brass Compressor Wind Tap ¼

3.2 Testing Results

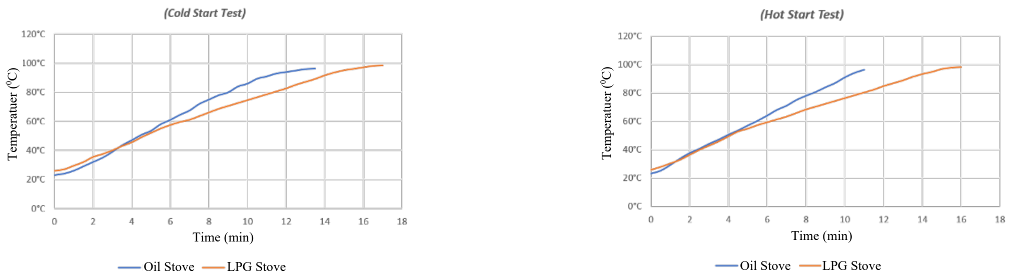
Performance testing was conducted using the WBT method in three stages: cold start, hot start, and simmering. The test results showed that the oil stove produced a blue flame and boiled water faster (a difference of 3–5 min) than the LPG stove, although it required an initial burning time of approximately 1–2 min and 3–5 min to reach a stable temperature.

Table 2: Test result data for oil stove and LPG gas stove.

Testing		Parameter									
		m (kg)	C_p (kj/kg)	L *(kj.kg)*	ΔT (^{0}C)	$B1$ (kg)	$B2$ (kg)	HVV (kJ.kg)	P (kW)	$t1$ (minutes)	$t2$ (minutes)
Oil Stove	***Cold start***	5	4,182	2250	73.4	0.150	0.172	42,400	0.03	13.5	15.5
	Hot start	5	4,182	2250	73.4	0.122	0.167	42,400	0.03	11.0	15.0
	Simmering	5	4,182	2250	72.0	-	0.220	42,400	0.03	-	45.0
LPG Gas	***Cold start***	5	4,182	2250	72.4	0.100	0.100	46,962	-	17.0	17.0
	Hot start	5	4,182	2250	72.4	0.094	0.097	46,962	-	16.0	16.5
	Simmering	5	4,182	2250	71.0	-	0.200	46,962	-	-	45.0

Description:

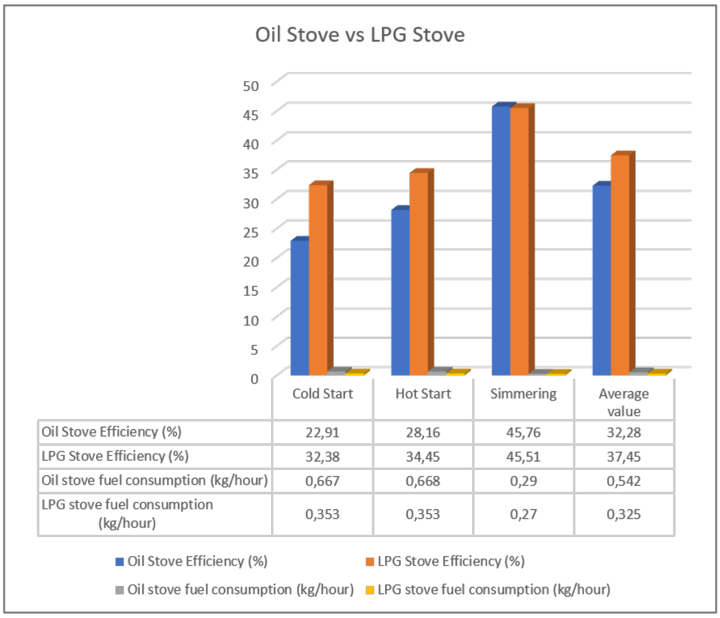
m = Mass of heated water
Cp = Specific heat of water
L = Latent heat of vaporization of water
ΔT = Change in water temperature
$B1$ = Water heating fuel consumption
$B2$ = Total fuel consumption
HV = Calorific value of fuel
P = Electric blower power
$t1$ = Water boiling time
$t2$ = Total burning time



(a) (b)

Figure 3. Graph comparing the increase in water temperature between a used oil stove and an LPG gas stove: (a) Cold Start Test and (b) Hot Start Test.

The test results (Table 2) show that the developed used-oil stove can boil 5 kg of water in a time competitive with a conventional LPG stove, particularly after the initial flame stabilization phase (Figure 3). This performance aligns with the broader literature on used oil stoves, which indicates that thermal efficiency is highly dependent on the design and operating parameters. Kotingo and Uchendu (2024) reported an efficiency of up to 70% for a drip-fed design under optimized conditions, demonstrating the potential of this technology. In contrast, Asmoro (2025) found efficiencies between 15–30% for smaller water volumes (1–3 L), highlighting a more typical range for practical, non-optimized applications. The present study's result of 32.28% (Figure 4) falls within this spectrum, corroborating the finding that efficiency is significantly influenced by stove engineering. This connection is reinforced by the review of Palanisamy et al. (2023), which systematically identifies combustion stability, airflow control, and overall design as critical determinants of liquid-fuel stove performance. Therefore, beyond providing a practical estimate of heating time, this study contributes empirical data that situates the performance of a locally fabricated, economical stove within the established scientific context, supporting its viability as an efficient energy alternative.



	Cold Start	Hot Start	Simmering	Average value
Oil Stove Efficiency (%)	22,91	28,16	45,76	32,28
LPG Stove Efficiency (%)	32,38	34,45	45,51	37,45
Oil stove fuel consumption (kg/hour)	0,667	0,668	0,29	0,542
LPG stove fuel consumption (kg/hour)	0,353	0,353	0,27	0,325

Figure 4. Graph and table of analysis results for oil stoves vs LPG gas stoves

Test results show that stoves fueled by used oil have an average thermal efficiency of 32.28%, which is slightly lower than that of LPG stoves, which reach 37.45% (Figure 4). However, this value meets the minimum efficiency standard of 30% stipulated in SNI 7926:2013 for household biomass stoves. An increase in efficiency was observed under simmering conditions, where the used oil stove reached 45.76%, which is close to the performance of the LPG stove (45.51%). This variation is in line with the findings of Kshirsagar and Kalamkar (2014), who emphasized that the design of the combustion chamber and air distribution significantly affect stove efficiency. In terms of fuel consumption, used oil stoves recorded an average Fuel Consumption Rate (FCR) of 0.542 kg/h, higher than LPG, which was only 0.325 kg/h.

Overall, although used oil stoves show higher fuel consumption, the thermal efficiency achieved is in line with the standards and has the potential to be improved through optimization of the combustion chamber design and air system. This finding supports the use of used oil as a viable alternative energy source for rural households.

3.3 Operational Cost Efficiency

In terms of fuel consumption, the used oil stove was higher than that of LPG at 0.325 kg/h. However, when operational costs show that the oil stove requires only Rp1,986 per day, while the LPG stove costs Rp6,500 per day (Table 3). Thus, there was a savings of approximately 69.45% in using the oil stove compared to the LPG stove. When compared with the average monthly income of farmers in North Sulawesi, Rp1,792,643, in 2023 (Badan Pusat Statistik Provinsi Sulawesi Utara, 2023), the use of oil stoves accounted for only approximately 0.3% of the farmers' monthly income. Conversely, LPG stoves can consume up to 11% of the income. This comparison shows that oil stoves have a significantly greater economic impact on farmers’ household energy security.

Table 3. Operating costs of oil stove and LPG gas stove

	Parameter	Per Day (3 hours)	Per Month (30 Days)
Stove Oil	*BB Oil Cost*	Rp. 1,860	Rp. 55,800
	Blower Electricity Cost	Rp. 126	Rp. 3,780
	Total operational cost	Rp. 1,986	Rp. 59,580
Gas Stove	*LPG fuel cost*	Rp. 6,500	Rp. 195,000
	-	-	-
	Total operational cost	Rp. 6,500	Rp. 195,000

According to Mordor Intelligence (2024), Indonesia’s finished lubricant market is forecast to reach 1.20 billion liters in 2025. Using this as a conservative proxy for the potential generation of used lubricating oil, the scale remains substantial, even if not all used oil can be collected. For illustration, 1% of the 2025 market volume, 12 million liters per year, or about 32,876 liters per day, could be allocated to waste-to-energy applications and would be sufficient to fuel roughly 65,750 oil stoves per day (assuming 0.5 L/stove/day). This highlights the strategic potential of used oil for supporting operations in the agricultural sector.

However, environmental safeguards are essential. Hernady et al. (2019) reported SO_2 emissions of ~4.5 μg/Nm³ from used-oil combustion under test conditions—below typical limits—yet particulate matter and heavy metals remain serious concerns. Therefore, appropriate combustion design and flue gas filtration are prerequisites for preventing air pollution and protecting both agricultural ecosystems and worker health (Hernady et al., 2019).

4. CONCLUSION

This study successfully designed and tested an economical stove fueled by used oil for household-scale post-harvest energy needs in an agricultural environment. The developed stove was able to produce an average thermal efficiency of 32.28%, which is slightly lower than that of the LPG stove (37.45%), but has exceeded the minimum standard of thermal efficiency according to SNI 7926:2013, which is 30%. In addition, in terms of operation, this stove showed significant cost efficiency with a daily cost of only Rp1,986, or equivalent to ± 69.45% savings compared to the use of LPG stoves.

The use of oil stoves is also more economically friendly for farmers because it only absorbs 3.9%-4.9% of farmers' monthly income in North Sulawesi, much lower than LPG, which can absorb up to 13-16%. The potential for utilizing used oil is also very large, with an estimated 379 thousand liters of waste oil available per day from motorcycles, which has the potential to light tens of thousands of stoves per day.

From an environmental perspective, this stove needs to be supported with a good emission disposal system to reduce the impact of particulates and heavy metal content. With a production cost of IDR 363,000 per unit and fairly high efficiency, this used oil stove offers an appropriate technological solution that is applicable, economical, and sustainable to support post-harvest activities and energy security of farmer households in agricultural areas.

REFERENCES

Akhyar. (2014, November 12). Perancangan Dan Pembuatan Tungku Peleburan Logam dengan Pemanfaatan Oli Bekas Sebagai Bahan Bakar. *Seminar Nasional Sains Dan Teknologi 2014*. https://jurnal.umj.ac.id/index.php/semnastek/article/view/323

Al-Omari, S. B. (2008). Used engine lubrication oil as a renewable supplementary fuel for furnaces. *Energy Conversion and Management*, *49*(12), 3648–3653. https://doi.org/https://doi.org/10.1016/j.enconman.2008.07.011

Asmoro, P. T. (2025). Efficiency and Electrical Power Consumption Analysis of Gasification Stove Fueled by Used Cooking Oil as A Renewable Energy Alternative. *Indonesian Journal of Energy*, *8*(2), 118–128. https://doi.org/10.33116/ije.v8i2.267

Badan Pusat Statistik Provinsi Sulawesi Utara. (2023). *Rata-rata Pendapatan Bersih Sebulan Pekerja Informal Menurut Kabupaten/Kota dan Lapangan Pekerjaan Utama di Provinsi Sulawesi Utara (rupiah), 2023*. Badan Pusat Statistik. https://sulut.bps.go.id/id/statistics-table/3/VVhCTlptdExibkpyV25WM2NFNWFXa3czVDFvdmR6MDkjMw==/rata-rata-pendapatan-bersih-sebulan-pekerja-informal-sup-1--sup--menurut-kabupaten-kota-dan-lapangan-pekerjaan-utama-di-provinsi-sulawesi-utara--rupiah---2023.html?year=2023

Badan Standardisasi Nasional. (2013). *SNI 7926:2013 Kompor biomassa rumah tangga – Persyaratan dan pengujian*.

BPS-Statistics Indonesia. (2023). *Distribusi Persentase Rumah Tangga Menurut Provinsi dan Bahan Bakar Utama untuk Memasak, 2023*. BPS-Statistics Indonesia. https://www.bps.go.id/id/statistics-table/3/Y2xkT1kwVmhNSFZLYm1WUVpXUXJNbXRvVkdjd1FUMDkjMw==/distribusi-persentase-rumah-tangga-menurut-provinsi-dan-bahan-bakar-utama-untuk-memasak--2023.html

Engineering Toolbox. (2025a). *Water - Properties vs. Temperature and Pressure*. https://www.engineeringtoolbox.com/water-properties-d_1258.html

Engineering Toolbox. (2025b). *Water Properties: Vaporization Heat vs. Temperature - Charts and Calculator*. https://www.engineeringtoolbox.com/water-properties-d_1573.html

Hernady, D., Septian, L., & Chandra, B. (2019). Perancangan, Pembuatan, dan Pengujian Burner Dengan Bahan Bakar Oli Bekas Dan Minyak Jelantah. *Seminar Nasional – XVIII Rekayasa Dan Aplikasi Teknik Mesin Di Industri*, TKE-41-TKE-47. http://eprints.itenas.ac.id/595/1/35%20TKE%2005%20Perancangan%2C%20Pembuatan%2C%20dan%20Pengujian%20Burner%20Dengan%20Bahan%20Bakar%20Oli%20%20Bekas%20Dan%20Minyak%20Jelantah.pdf

Kotingo, K., & Uchendu, I. F. (2024). Design Analysis and Development of a Drip-Fed Waste Oil Stove for Domestic Cooking. *SSR Journal of Multidisciplinary (SSRJM)*, *1*(2), 95–103. https://doi.org/10.5281/zenodo.15814626

Kshirsagar, M. P., & Kalamkar, V. R. (2014). A comprehensive review on biomass cookstoves and a systematic approach for modern cookstove design. *Renewable and Sustainable Energy Reviews*, *30*, 580–603. https://doi.org/https://doi.org/10.1016/j.rser.2013.10.039

Monika, Banga, S., & Pathak, V. V. (2023). Biodiesel production from waste cooking oil: A comprehensive review on the application of heterogenous catalysts. *Energy Nexus*, *10*, 100209. https://doi.org/https://doi.org/10.1016/j.nexus.2023.100209

Mordor Intelligence. (2024). *Indonesia Lubricants Market Size & Share Analysis - Growth Trends And Forecast (2025 - 2030)*. Https://Www.Mordorintelligence.Com/Industry-Reports/Indonesia-Lubricants-Market-Industry. https://www.mordorintelligence.com/industry-reports/indonesia-lubricants-market-industry

North Sulawesi Provincial Government. (2025). *Realisasi Distribusi LPG 3 Kg Sulawesi Utara Capai 43,79 Juta Tabung Hingga 8 Juni 2025*. Biro Ekonomi, North Sulawesi Provincial Government. https://apps-biroekonomi.sulutprov.go.id/listberita/948

Palanisamy, M., Kaushik, L. K., Mahalingam, A. K., Deb, S., Maurya, P., Shaik, S. R., & Mujeebu, M. A. (2023). Evolutions in Gaseous and Liquid Fuel Cook-Stove Technologies. In *Energies* (Vol. 16, pp. 1–37). MDPI. https://doi.org/10.3390/en16020763

Patel, N., & Shadangi, K. P. (2020). Thermochemical conversion of waste engine oil (WEO) to gasoline-rich crude oil. *Journal of Material Cycles and Waste Management*, *22*(2), 536–546. https://doi.org/10.1007/s10163-019-00948-9

Pratama, A., Basyirun, B., Atmojo, Y. W., Ramadhan, G. W., & Hidayat, A. R. (2020). Rancang Bangun Kompor (Burner) Berbahan Bakar Oli Bekas. *Mekanika: Majalah Ilmiah Mekanika*, *19*(2), 95. https://doi.org/10.20961/mekanika.v19i2.42378

Rama Pien, M., Haerani, & Munir, A. (2024). Comparative Analysis of the Performance of Gasoline and LPG-Powered Water Pumps in Shallow Wells. *Salaga Journal*, *1*(1), 1–7. https://doi.org/10.70124/salaga.v1i1.1102

Silaban, R., Simanjuntak, J., Firdaus, F., Lubis, I., & Ginting, L. (2025, January 25). Experimental Study of Used Lubricant Oil Combustion as an Alternative Energy Source. *Proceedings of the 5th International Conference on Innovation in Education, Science, and Culture, ICIESC 2023, 24 October 2023, Medan, Indonesia*. https://doi.org/10.4108/eai.24-10-2023.2342045

Sudarno, S., Fadelan, F., Setyatinika, W. A., & Winardi, Y. (2024). The Effect of Fuel Preheating on The Performance of Used Oil Fuel Stoves. *Journal of Applied Engineering Science*, *22*(3), 564–572. https://doi.org/10.5937/jaes0-48185

Syam, J. N., Diyah, Y., & Salengke, S. (2025). Production of Biochar from Sago Dregs Using NaOH Pretreatment and Microwave Pyrolysis. *Salaga Journal*, *3*(1), 1–5. https://doi.org/10.70124/salaga.v3i1.1809

World Nuclear Association. (2025, September 30). *Heat Values of Various Fuels*. https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels

Zahir Hussain, A., Santhoshkumar, A., & Ramanathan, A. (2020). Assessment of pyrolysis waste engine oil as an alternative fuel source for diesel engine. *Journal of Thermal Analysis and Calorimetry*, *141*(6), 2277–2293. https://doi.org/10.1007/s10973-020-09516-y