Efficiency and Electrical Power Consumption of Prototype-2 Gasification Stove Fueled by Used Cooking Oil

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Abstract. *Currently, society and the business still rely on 3 kg and 12 kg LPG gas stoves for cooking. And the supply of LPG in Indonesia is 6.7 million tons, or about 77%; it is still imported from abroad. On the other hand, used cooking oil (Used Cooking Oil/UCO) produced in Indonesia is around 1.2 million kiloliters per year, which proves that Indonesia has a fairly abundant supply of used cooking oil. This used cooking oil, if still used for frying, can be harmful to health, and if disposed of in the environment, will pollute water and soil. Therefore, an innovation arose to create a gasification stove by utilizing waste-used cooking oil that is no longer used as fuel for the stove as a form of appropriate technology that is sourced from renewable energy that is environmentally friendly. This study aims to analyze the efficiency of used cooking oil stoves using the Water Boiling Test (WBT) method, where testing and analysis were carried out using 3 samples of 1 liter of water volume. The test and analysis results showed that the average thermal efficiency was 54.4%, exceeding the minimum requirement of 50%, according to the SNI 8660:2018 standard. The average Fuel Consumption Rate (FCR) value was 0.44 liters/hour, and the average input power (Pin) was 3.58 kW, exceeding the average input power for LPG gas stoves of 2.37 kW. Meanwhile, the electrical power required to operate the stove was 430.1 Watts.*

Keywords – *Stove; UCO; Efficiency; Electrical-Power; Renewable-Energy*

INTRODUCTION

Society and business still rely on 3 kg and 12 kg LPG gas stoves for cooking. And the supply of LPG in Indonesia is 6.7 million tons, or around 77%, which is still imported from abroad [1]. On the other hand, Used Cooking Oil (UCO) produced in Indonesia is around 1.2 million kiloliters per year [2]. Making Indonesia one of the countries that produces the largest amount of used cooking oil in the world. This used cooking oil, if still used for frying, can be dangerous for health, and if disposed of into the environment, will pollute water and soil [3] [4] [5] [6]. This research is a continuation of the previous research entitled Efficiency and Electrical Power Consumption Analysis of Gasification Stove Fueled by Waste Cooking Oil as a Renewable Energy Alternative, where the previous research obtained results in the form of thermal efficiency of 30.49% and Fuel Consumption Rate (FCR) of 1 liter/hour, with the electrical power used to operate the stove of 10.89 Watts [7]. The purpose of this research is to recycle used cooking oil waste that is no longer used into fuel for a stove with better thermal efficiency than previous research, as a form of contribution to the development of renewable energy up to 60% of world energy in 2030 [8]. The prototype of the stove using used cooking oil as fuel, the result of previous research, is presented in Figure 1.

Figure 1. Prototype-1 Stove Using Used Cooking Oil as Fuel In The First Research

METHOD

The method applied in this research is an experimental method, where the used cooking oil stove that has been designed and fabricated is tested to obtain thermal efficiency, Fuel Consumption Rate (FCR), output power, and electrical power of the used cooking oil stove. From the test results, conclusions are obtained about the performance of used cooking oil and its comparison with other stoves, for example, the comparison of cooking time between used cooking oil stoves and LPG stoves. Used cooking oil has a flash point of 240 – 300°C, with a calorific value of 9197.29 kcal/kg [9]. So it can be a fuel at a maximum temperature of 300°C, and if the combustion is oxygenated in the combustion chamber furnace (gasification), then perfect combustion will occur. The way this stove works, among other things, there is an air hole in the nozzle pipe that is perpendicular to the combustion chamber furnace so that the air flow will be directed to the furnace wall. This aims to make the combustion process perfect [10], because the composition of oxygen that is greater than the fuel will eliminate combustion smoke [11]. The next process, the fire mixed with air coming out of the nozzle pipe, is directed to the wall of the combustion chamber furnace and bounces upwards so that it hits the cooking utensil container so that it can be used to heat or cook food [7] [12]. The following is a schematic of the Prototype-2 stove fueled by waste cooking oil, which is equipped with an Automatic Fuel Supply System [13]:

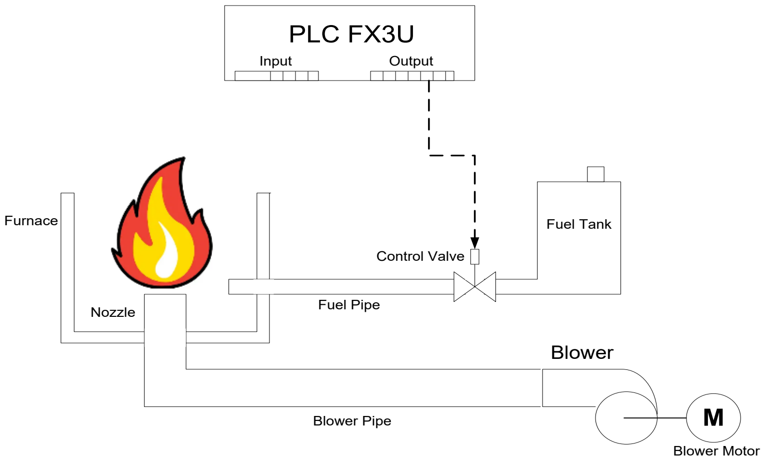

Figure 2. Schematic of Prototype 2 Used Cooking Oil Stove

Unlike previous research prototypes, Prototype-2, the used cooking oil stove, is equipped with an FX3U PLC-based Automatic Fuel Supply System. This automatic device allows for more efficient fuel usage and tailoring to needs. The following is a wiring diagram of the FX3U PLC-based Automatic Fuel Supply System:

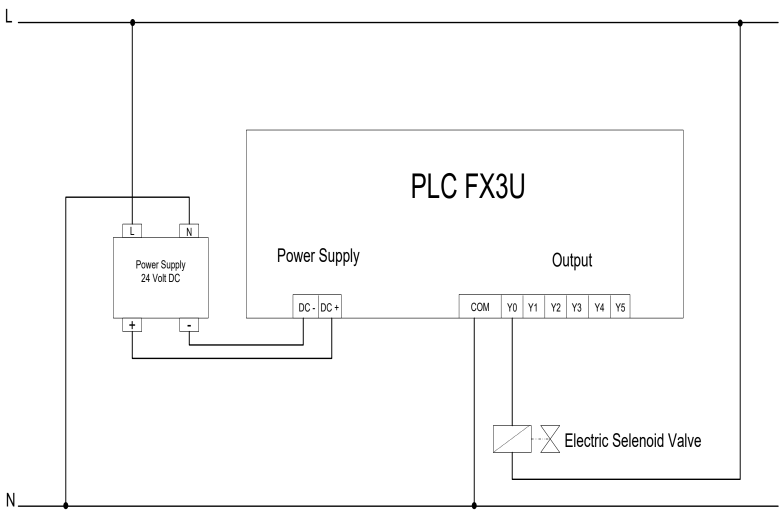

Figure 3. Wiring Diagram of an Automatic Fuel Supply System Based on the FX3U PLC

Figure 3 illustrates that the fuel supply system uses an electrical system, where the fuel supply is controlled by the FX3U PLC as the controller. The FX3U PLC receives its power supply from a 24-volt DC power supply. The FX3U PLC output is connected to an electric solenoid valve, allowing the FX3U PLC to control the valve's opening and closing to ensure optimal and efficient fuel supply. The following is a prototype 2 stove fueled by used cooking oil equipped with an Automatic Electric Fuel Supply System based on the FX3U PLC Controller:

Figure 4. Prototype 2 Stove Fueled by Waste Cooking Oil with Automatic Fuel Supply System

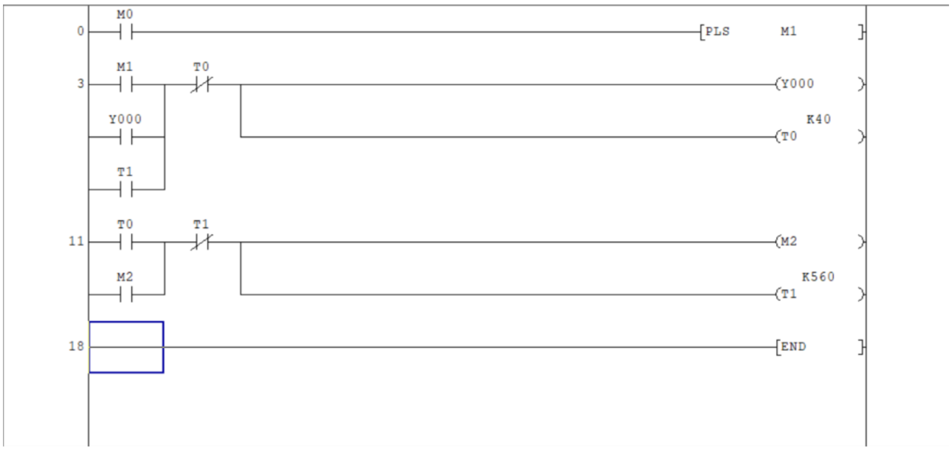

Figure 5. PLC Program for Controlling the Opening and Closing of a Solenoid Valve Using a Timer

The fuel supply system on the prototype-2 stove fueled by used cooking oil uses a solenoid valve open-close system using a timer, where the timer in the PLC program in figure 5 regulates the output connected to the solenoid valve so that the solenoid valve opens for 4 seconds and closes for 560 seconds automatically and continuously for 1 minute, which is shown in figure 6. Each solenoid valve opens for 4 seconds and will flow fuel from the tank as much as 6.5 milliliters, producing combustion heat with a temperature of about 500°C and an average thermal efficiency of about 54.4%. Meanwhile, if the valve is opened and closed manually, the fuel supply becomes unstable, which causes the fuel supply to sometimes be reduced, which results in a low combustion temperature, thus reducing thermal efficiency. However, manually opening and closing the valve can lead to an excessive fuel supply, filling the combustion chamber with fuel and causing the pressurized air nozzle hole to close, which disrupts the combustion process.

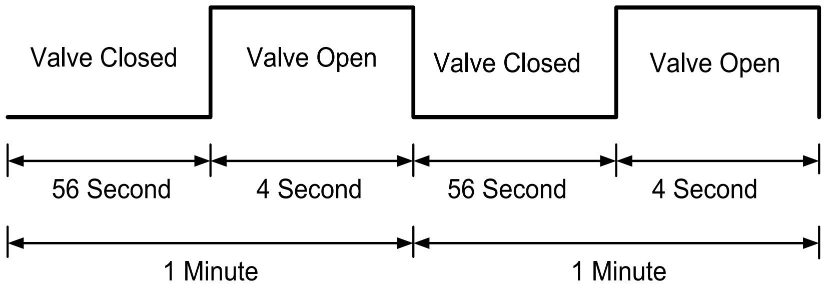

Figure 6. Solenoid Valve Opening and Closing System for Continuous Fuel Supply

The fabricated prototype will then be tested for its performance through a thermal efficiency test using the Water Boiling Test (WBT) method using the following formula:

$$\eta = \frac{SH + LH}{QF} .100\% \tag{1}$$

Thermal efficiency is the ratio of the calorific value absorbed by water to the calorific value contained in the fuel. Thermal efficiency is the sum of the Sensible Heat (kcal), *SH*, and Latent Heat (kcal), *LH*, divided by the heat energy available in the fuel (kcal), *QF* [14].

To determine the Fuel Consumption Rate (FCR), the following formula can be used:

$$FCR = \frac{Q_n}{HVF \, .\eta} \tag{2}$$

Fuel Consumption Rate (kg/hour), FCR, is the result of dividing the required heat energy (kcal/hour), Q_n, by the heating value of the fuel (kcal/kg), *HVF*, and the thermal efficiency, η [14].

The heat input power can be determined using the following formula:

$$P_i = FCR \, .HVF \tag{7}$$

Where the Heat Input Power (Watt), P_i, is the result of multiplying the Fuel Consumption Rate (Kg/Hours), FCR, by the heating value of the fuel (kcal/kg), *HVF* [14].

RESULT AND DISCUSSION

Table 1 shows the test results of Prototype-2 gasification stoves fueled by used cooking oil. From these test results, calculations and analysis will be carried out to determine the values of Thermal Efficiency (η), Fuel Consumption Rate (FCR), and Input Power (Pin). Stoves generally use LPG gas as fuel, and according to research results, LPG gas has a range of heat input power (Pin) values between 1.72 kW and 2.8 kW, with an average heat input power value of 2.37 kW [15]. Meanwhile, according to the SNI 8660:2018 Standard regarding stove performance efficiency, it is stated that the efficiency of a stove (stove) that meets the standard must have a minimum value of 50% for tabletop stoves and 45% for built-in stoves and standing stoves [15].

Table 1. Measurement results before and after boiling

Attempt	Before Boiling			After Boiling			Boiling time (Minutes)
	Initial volume of water (Liters)	Initial fuel volume (Liters)	Initial water temperature (°C)	Final volume of water (Liters)	Final fuel volume (Liters)	Final water temperature (°C)	
1	1	1	30.2	0.92	0.7	100.8	2.18
2	1	1	31	0.91	0.7	100.3	1.95
3	1	1	29.8	0.91	0.7	98.9	2.32

From the test results of the parameters of the prototype-2 stove in table 1, calculations and analysis were carried out to obtain the values of Thermal Efficiency (η), Fuel Consumption Rate (FCR), and Input Power (Pin), which are shown in table 2 below:

Table 2. Thermal efficiency, FCR, and input power of Prototipe-2 UCO stove

Volume of water boiled (Liters)	Attempt	Thermal efficiency (η) (%)	FCR (Liters/hour)	Input power (Pi) (Watt)
1	1	53.2	0.45	3,642.66
1	2	55.1	0.47	3,858.45
1	3	55	0.4	3,239.23
Average Value		54.4	0.44	3,580.11
Standard Deviation		0.87	0.029	256.63

Thermal Efficiency

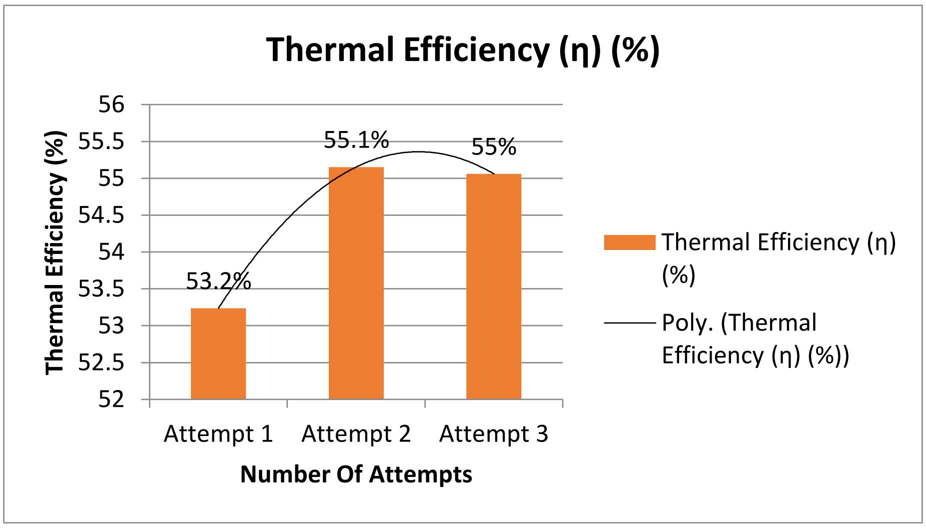

Figure 7. Thermal Efficiency of Prototype-2 Stove Fueled by Waste Cooking Oil

Figure 7 shows a graph of the thermal efficiency value in the prototype-2 gasification stove test using waste cooking oil using the Water Boiling Test (WBT) method, whereinthe test, 1 liter of water was boiled with 3 trials. In the first trial, a thermal efficiency value of 53.2% was obtained. In the second trial, a thermal efficiency value of 55.1% was obtained. And in the third trial, the thermal efficiency value was 55%. With an average thermal efficiency value of 54.4%, with Standard Deviation 0.87 in 3 trials. The results of the analysis show that the thermal efficiency value of the prototype-2 stove has exceeded the minimum requirement, which is 50%, according to the SNI 8660:2018 standard, so it can be concluded that the prototype-2 stove has met the stove efficiency performance standard.

Fuel Consumption Rate (FCR)

The Fuel Consumption Rate (FCR) graph for the prototype-2 stove is shown in Figure 8. Based on the results of three tests on the prototype-2 stove boiling 1 liter of water, the FCR values were 0.45 liters/hour, 0.47 liters/hour, and 0.4 liters/hour, respectively, with an average FCR of 0.44 liters/hour. This means that the average fuel used by the stove in one hour is 0.44 liters, or 440 ml. There is no standard for the Fuel Consumption Rate (FCR) for stoves in general, but the test results show that an average FCR of 0.44 liters/hour is quite good, as it is still below 1 liter/hour, with Standard Deviation 0.029.

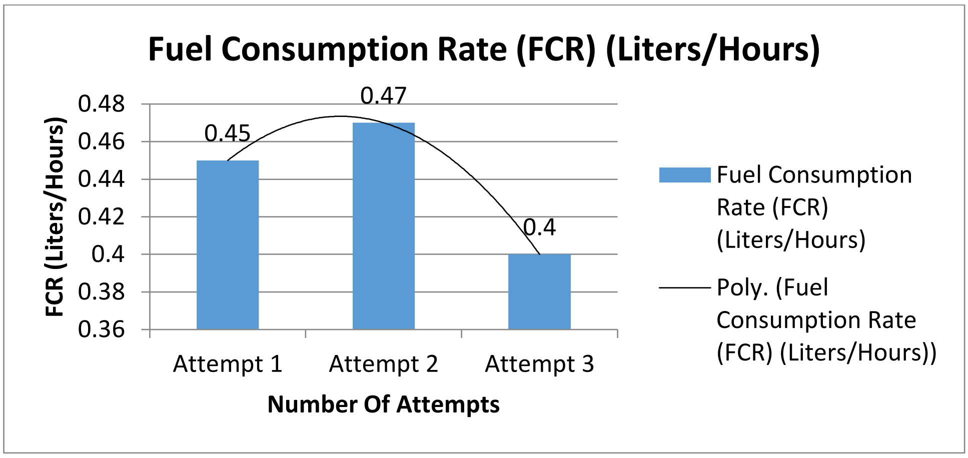

Figure 8. Fuel Consumption Rate (FCR) of Prototype-2 Stove Fueled by Waste Cooking Oil

Heat Input Power (Pin)

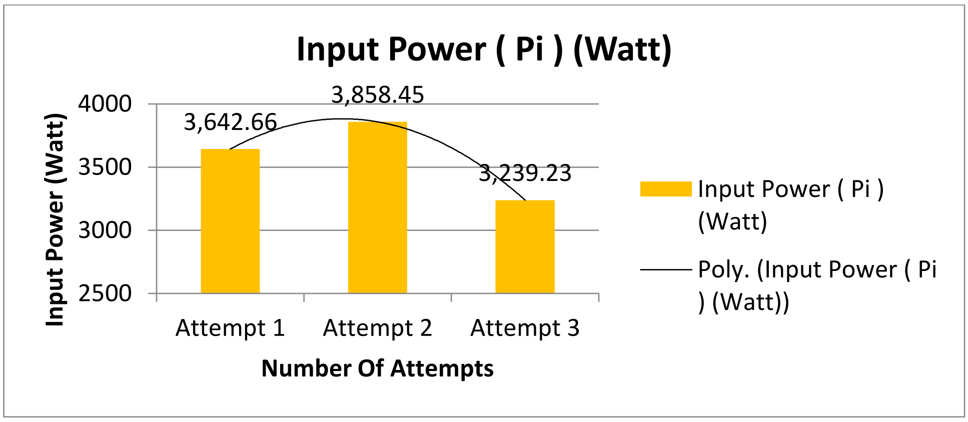

Figure 9. Heat Input Power (Pin) of Prototype-2 Stove Fueled by Waste Cooking Oil

The heat input power (Pin) graph for the prototype-2 stove is shown in Figure 9. Based on the results of testing the prototype 2 stove on boiling 1 liter of water three times, the heat input power values were 3,642.66 Watts, 3,858.45 Watts, and 3,239.23 Watts, respectively, with an average heat input power of 3,580.11 Watts or 3.58 kW, with Standard Deviation 256.63. Compared to an LPG-fueled stove, which has an average heat input power of 2.37 kW [15], the prototype 2 stove has a better heat input power than the LPG-fueled stove.

Electrical Consumption of Prototype-2 Stove Fueled By Waste Cooking Oil

The electrical circuit of the prototype-2 stove fueled by used cooking oil waste consists of a PLC FX3U microcontroller, a solenoid valve for fuel, and a blower. The measured electric current is 2.3 amperes, while the measured electric voltage is 220 volts (AC), and if the power factor (Cos φ) is 0.85, then the electric power of the prototype-2 stove fueled by used cooking oil waste is 430.1 Watts. In previous research, the blower used in the prototype-1 stove fueled by used cooking oil waste was 10.89 Watts, and produced a thermal efficiency of 30.49%. While in the prototype-2 stove, the blower used has a power of 260 Watts, and produces an average thermal efficiency of 54.4%. Based on the experimental results, it was concluded that the greater the blower power, the greater the effect on thermal efficiency, because the greater the blower power, the greater the blower's ability to flow air into the furnace chamber so that in the furnace chamber perfect combustion occurs, and thermal efficiency increases.

Figure 10. Flame Produced By the Prototype-2 Stove Fueled By Used Cooking Oil

CONCLUSION

The results of testing and analysis on the prototype 2 stove fueled by used cooking oil showed an average thermal efficiency of 54.4%, exceeding the minimum requirement of 50% according to the SNI 8660:2018 standard. Therefore, it can be concluded that the prototype 2 stove meets the stove efficiency performance standards. The Fuel Consumption Rate (FCR) was 0.44 liters/hour, and the average input power was 3,580.11 Watts or 3.58 kW, exceeding the average input power for LPG-fueled stoves of 2.37 kW. The electrical power of the prototype 2 stove fueled by used cooking oil was 430.1 Watts. In the previous prototype 1 study, the stove blower power was 10.89 Watts, resulting in a thermal efficiency of 30.49%. Meanwhile, on the prototype-2 stove, the stove blower power of 260 Watts can produce an average thermal efficiency of 54.4%, meaning that the greater the blower power, the greater the blower's ability to flow air into the furnace chamber so that perfect combustion occurs in the furnace chamber and increases thermal efficiency. If further developed, the Prototype-2 Stove, which runs on used cooking oil, could be directly implemented for users in food businesses, catering businesses, restaurants, and hotels. Its combustion temperature, reaching 500°C, allows for rapid cooking, thus expediting food preparation. The first step is to conduct an emissions test on the stove to ensure that the gas emissions it produces do not cause pollution that could harm users.

REFERENCES

[1] Direktorat Jenderal Minyak Dan Gas Bumi, “Pertamina sesuaikan harga elpiji 12 Kg,” 2008. [Online]. Available: https://migas.esdm.go.id/post/Pertamina-Sesuaikan-Harga-Elpiji-12-Kg. [Accessed: 07-Nov-2024].

[2] A. S. (Traction E. A. Sari, “Produksi minyak jelantah Indonesia mencapai 1,2 juta kilo liter,” 2023. [Online]. Available: https://tractionenergy.asia/id/produksi-minyak-jelantah-di-indonesia-mencapai-12-juta-kiloliter/. [Accessed: 07-Nov-2024].

[3] M. Irsyad, Amrizal, Harmen, Amrul, M. D. Susila Es, and A. R. Diva Putra, “Experimental study of the thermal properties of waste cooking oil applied as thermal energy storage,” *Results Eng.*, vol. 18, no. March, p. 101080, 2023, doi: 10.1016/j.rineng.2023.101080.

[4] A. Kumar, H. S. Pali, and M. Kumar, “Evaluation of waste plastic and waste cooking oil as a potential alternative fuel in diesel engine,” *Next Energy*, vol. 5, no. August, p. 100181, 2024, doi: 10.1016/j.nxener.2024.100181.

[5] S. Nkosi, J. O. Unuofin, O. A. Odeniyi, S. A. Iwarere, and M. O. Daramola, “Harnessing microbial potential: Exploiting heavy oil-laden soil microbiota for sustainable production of high-yield rhamnolipids from waste cooking oil,” *Biocatal. Agric. Biotechnol.*, vol. 61, no. September, p. 103371, 2024, doi: 10.1016/j.bcab.2024.103371.

[6] A. K. Hossain, V. Sharma, C. Serrano, A. Krishnasamy, and D. Ganesh, “Production of biofuel from AD digestate waste and their combustion characteristics in a low-speed diesel engine,” *Renew. Energy*, vol. 222, no. September 2023, p. 119884, 2024, doi: 10.1016/j.renene.2023.119884.

[7] P. T. Asmoro, “Efficiency And Electrical Power Consumption Analysis Of Gasification Stove Fueled Waste Cooking Oil As A Renewable Energy Alternative,” pp. 1–13, 2024.

[8] X. Zhang, D. Feng, J. Wang, and A. Sui, “Integrating renewable energy systems: Assessing financial innovation, renewable energy generation intensity, energy transition and environmental regulation with renewable energy sources,” *Energy Strateg. Rev.*, vol. 56, no. October, p. 101567, 2024, doi: 10.1016/j.esr.2024.101567.

[9] F. . Hasan, B. Tarigan, and Anasril, “Pengaruh Banyaknya Penambahan Minyak Goreng Bekas ke Minyak

Solar Terhadap Nilai Panas Bahan Bakar yang Dihasilkan," *Bul. Utama Tek.*, vol. 17, no. 2, pp. 129–132, 2022.

[10] T. Sathish, "Combustion and emission performance analyzes on the blend of waste cooking oil / Azadirachta indica oil biodiesel / carbon nano tubes in diesel engines," *Int. J. Thermofluids*, vol. 24, no. November, p. 100964, 2024, doi: 10.1016/j.ijft.2024.100964.

[11] A. Rebryk, I. Kozyatnyk, and M. Njenga, "Emission of volatile organic compounds during open fire cooking with wood biomass: Traditional three-stone open fire vs. gasifier cooking stove in rural Kenya," *Sci. Total Environ.*, vol. 934, no. March, p. 173183, 2024, doi: 10.1016/j.scitotenv.2024.173183.

[12] D. U. Suwarno, W. Widyastuti, H. Sriwindono, L. Purwoto, and B. W. Harini, "Kompor Minyak Jelantah: Kinerja dan Keberlanjutan dalam Pemanasan Air Rumah Tangga," *Pros. SENAPAS*, vol. 2, no. 1, pp. 73–78, 2024.

[13] J. Liu, J. Zhao, Q. Zhu, D. Huo, Y. Li, and W. Li, "Methanol-based fuel boiler: Design, process, emission, energy consumption, and techno-economic analysis," *Case Stud. Therm. Eng.*, vol. 54, p. 103885, 2024, doi: 10.1016/j.csite.2023.103885.

[14] M. F. Aryansyah, H. Santoso, and M. F. Nurdin, "Analisis Efisiensi Termal Pada Kompor Biomassa Dengan Menggunakan Water Boiling Test (WBT)," *J. Bear. Borneo Mech. Eng. Sci.*, vol. 1, no. 1, pp. 1–8, 2022.

[15] N. Kusnandar, W. S. Ramadhani, and I. Paramudita, "KARAKTERISTIK KINERJA KOMPOR GAS LPG MENGGUNAKAN BAHAN BAKAR DME DENGAN VARIASI DIAMETER NOZZLE DAN TEKANAN KERJA KOMPOR Performance Characteristics of LPG Stoves Using DME Fuel with Variations in Nozzle Diameter and Input Pressure," pp. 199–210, 2020.