INTERNATIONAL JOURNAL of SMART GRID
S. Salim, and A. I. Tolago, Vol. 7, No.3, September, 2023

Use of Coconut Shell Become an Alternative Electricity

Sardi Salim[1], Ade Irawaty Tolago[2]

1Department of Electrical Engineering, Faculty of Engineering, Gorontalo State University, Indonesia

2Department of Electrical Engineering, Faculty of Engineering, Gorontalo State University, Indonesia

(sardi@ung.ac.id, adeirawty@ung.ac.id)

‡Corresponding Author, Postal address, Tel: +62 812 8882 3621,

Fax: +435 821125, rektorat@ung.ac.id

Received: 06. 07.2023 Accepted: 10.08.202

Abstract- The level of non-renewable energy reserves is currently low, necessitating the need for alternative sources such as renewable energy. Renewable energy sources are natural and readily available. For instance, coconut shells are widely available throughout Indonesia and can be used as a renewable energy source. This study aims to determine the value of electrical energy generated from coconut shells with various compositions. The research method employed the experimental method. Initially, the coconut shell material was transformed into bio briquettes, which must adhere to the Indonesian National Standard 01-6235-2000, with a maximum water content of 8%, to be considered of good quality. A test was conducted using a biomass stove to determine the combustion rate. The results indicate that coconut shell-based bio briquettes have better quality. For a mass of 200 grams, the water content was 6.48%, and the cellulose value was 35%. The resulting calorific value was 5664.8 cal/gram, and the burning rate was 0.236 gram/minute. The Thermoelectric Module can convert energy from coconut shell bio briquettes weighing between 200-400 grams into an average of 13.35 Wh of electrical energy.

Keywords: renewable energy, coconut shell, thermoelectric, energy resources, electrical energy.

1. Introduction

The use of fossil fuels has led to significant environmental pollution and energy security issues [1], [2]. Greenhouse gas emissions resulting from the use of fossil fuels can cause global warming, which in turn can lead to cognitive and behavioral development disorders, respiratory diseases, and other chronic illnesses [3], [4]. Furthermore, the decreasing reserves of fossil fuels raise concerns about their resilience and sustainability. As a result, it is imperative to develop new and renewable sources of energy [5], [6], [7].

In Indonesia, Government Direction of the Republic of Indonesia Number 79 of 2014 outlines policies for new and renewable energy as part of the National Vitality Arrangement. In this regard, the aim is to achieve a minimum of 23% of modern and renewable energy by 2025 and at least 31% by 2050. Conversely, there is a target to reduce dependence on oil and coal by 20% and 25%, respectively [8], [9]. To meet long-term energy needs and prevent environmental impacts from using fossil fuels, the demand for renewable energy sources is expected to increase. This is due to the fact that the concentration of carbon dioxide (CO2) in the atmosphere is increasing, which can cause climate change [10], [11].

Natural raw materials and renewable energy sources in Indonesia are generally available in substantial quantities. As one of the raw materials for renewable energy sources, coconut trees are found in large quantities in almost all regions of Indonesia. The coconut tree is a plant whose parts can be utilized. In some communities, most coconut processing is only for the contents of the Coconut. In contrast, the coconut shell and coir are mostly left as waste.

Coconut shells can now be used as a raw material for biomass. Coconut shell is a material that can produce high heat for a long time. To be used as a raw material for biomass, coconut shells are first processed into bio-briquettes. Making bio-briquettes begins with the drying process in the sun. After the raw material is sufficiently dry, the combustion process is carried out to turn the material into charcoal. Raw materials are combined in a combustion tube to keep the sample collected properly. The combustion process is declared complete, marked by thinning smoke from the tube. The combustion process is shown in Fig 1.

(a) (b) (c)

(d) (e) (f)

Fig 1. The process of burning raw materials from ingredients to charcoal

After the burning process, the charcoal is aerated until it cools. The process of making bio-briquettes from coconut shell raw materials involves cooling, pounding, sieving, mixing with water and starch glue, printing using molds, and drying. The quality of the bio-briquettes produced for energy is affected by the process of making them. Biobriquettes produced under high pressure will be denser and have smaller pores, resulting in a longer burning rate. The use of biobriquettes as a substitute for coal in steam power plants can produce electrical energy. “Fig. 2” illustrates printed coconut shell biobriquettes.

Fig 2. Coconut shell-based bio briquettes.

Bio-briquettes are a viable alternative energy source for several reasons [12], [13].

a. Biobriquettes can be made using various materials such as corn cobs, coconut shells, and sawdust.
b. The fuel is easily
c. produced and can be used practically and efficiently. Once finished, the briquettes only need to be burned to release heat energy for cooking or other purposes.
d. Briquettes are a more economical alternative to oil and gas fuels, and can even be made at home.

Briquettes are more environmentally friendly than fuel oil and gas. The fire is extensive, but the smoke and what is produced are much less than charcoal. This can reduce carbon emissions, one of the leading causes of global warming. Not only that, briquettes can also be made from organic waste, so they can reduce the waste around us.

Quality bio briquettes have smooth textures, are not easily broken, are challenging, are safe for humans and the environment, and have good burning properties. The combustion properties include being easy to ignite, burning time being quite long, not causing soot, smoke being slight and quickly dissipating, and producing a relatively high calorific value. Utilization of biomass briquettes thermally can take the form of pyrolysis, gasification, or ordinary combustion processes.

2. Methods

The research method uses an experimental method, namely conducting trials of making bio-briquettes with coconut shells as an alternative energy substitute for non-renewable energy in producing electrical energy. Before carrying out the bio-briquette calorific value test, the water content test was carried out on the bio-briquette samples.

Content is a measure of the amount of water contained in a material. In fuel, the water content consists of two forms: the water content in solid fuel, namely free water in the pores and gaps of the fuel, and bound water, which is part of the chemical structure of the fuel [14], [15]. Moisture content measurement can be carried out with previously weighed samples and dried in an oven at 105 ºC after obtaining consistency according to the sample mass. The percentage of water content in the material can be known from the change in its weight. Moisture content can significantly affect the combustion characteristics of biomass. During combustion, water vapor in the biomass will absorb heat from the burning material and form hot steam, thereby reducing the heating value of the material. This can result in incomplete combustion. Materials that have a high moisture content can have difficulty igniting. The water content of a material is determined using equation (1) [16] [17].

$$PMC = \frac{W1-W2}{W2}\ x\ 100\% \tag{1}$$

Where: W_1 is the initial mass of the briquette sample, and W_2 is the final mass of the briquette sample.

The volatile matter value in biobriquettes can be determined by knowing compounds other than water, ash, methane, hydrocarbons, and carbon monoxide that will cause smoke when the briquettes are ignited. This is caused by a reaction between carbon monoxide (CO) and alcohol derivatives. The equation used is [18]:

$$PMC = \frac{W1-W2}{W2}\ x\ 100\% \tag{2}$$

Where: VM = volatile matter (%), mi = initial dry mass (g) and mf = mass after the end of the analysis (g).

2.1 Calorific Value of Biobriquettes

The calorific value is the number of heat units produced per unit volume with complete combustion [19], [20]. The testing steps are as follows:

a. Weigh the refined sample of approximately 1 gram and then press it into the form of a pellet.
b. Measure 10 cm of fuse wire, connect it to each electrode, and apply it to the sample pellet in the bomb.
c. Fill the bomb with oxygen to a maximum of 30 atm.
d. Close the gas flow control, wait a few moments, then remove the remaining oxygen in the hose until the regulator shows zero.
e. Fill the bucket with ± 1.5 liters of distilled water.
f. Place the bucket in the calorimeter, insert the bomb into the bucket until it is in position, and then connect the cable terminal to the bomb.
g. Close the calorimeter, connect the stirrer, and wait 5 minutes until the temperature of the distilled water in the bucket does not change.
h. Record the initial temperature on the thermometer.
i. Press the ignition unit until the indicator light turns off; continue pressing ± 5 minutes.
j. Record the temperature rise on the thermometer.
k. Wait ±3 minutes, then record the final temperature on the thermometer.
l. Open the calorimeter and remove the bomb; remove the remaining oxygen gas from the bomb so it is ultimately used up.
m. Rinse the surface of the bomb and transfer the water from the bucket into the Erlenmeyer.
n. Measure the remaining unburnt fuse wire.

After obtaining data from temperature change values in the briquette test using a bomb calorimeter, the calorific value can be calculated using equation 3 [21].

$$CV = \frac{BF\ x\ \Delta t - 2.3\ length\ of\ wire}{W} \tag{3}$$

Where: CV= calorific value, BF= Burn Factor, Δt= Change of temperature (t2 – t1) ºC, W=mass of the sample used and BF = constant = 13,257.32

2.2 Burning Rate

Testing the combustion rate is done manually using a briquette furnace. Where is the flame duration of each biobriquette mixture assessed to determine which one is more durable to flame? Before carrying out mass testing, each sample is weighed. Then each sample was burned to ashes. The burning time is calculated using a stopwatch, and the mass of ash is weighed again to determine the difference in the mass burned. This burning rate test is intended to determine the level of bio-briquette fuel efficiency. The equation used to obtain the combustion rate value is [22], [23]:

$$BR = \frac{Q_1 - Q_2}{T} \tag{4}$$

Where: *BR* = combustion rate (g/min), Q_1 = initial weight of material before combustion (g), Q_2 = final weight of material after combustion (g), and *T* = total burning time (minutes).

2.3 Heat Conversion of Biobriquettes into Electrical Energy

Changing over bio briquettes warmth into electrical vitality is carried out employing a thermoelectric generator. A thermoelectric generator could be a solid-state gadget that changes over warm flux (temperature contrast) into electrical energy. The working guideline of the thermoelectric generator is that when there's a temperature distinction between two diverse materials (metals or semiconductors), a voltage will be produced, specifically the Seebeck voltage. This marvel is connected to thermocouples, which are broadly utilized for temperature estimation. Based on the Seebeck impact, thermoelectric gadgets can act as control generators [24].

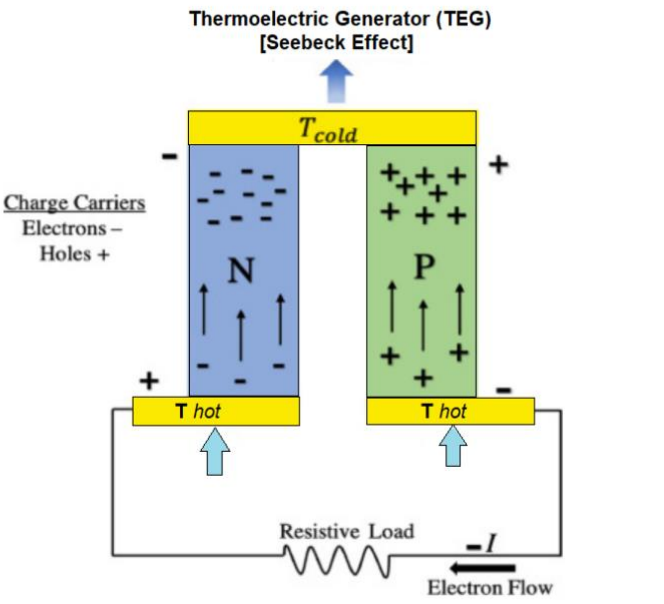

Fig 3. The working principle of Thermoelectric Generator

2.4 The thermoelectric generator

Heat is transferred at the rate of QH from a high-temperature, warm source. The warm exchange TH is rejected at the QL level for the low-power sink TL from the cold room with a criticism impact. The exchanged heat causes an electric current to stream within the circuit. Utilizing the laws of thermodynamics (the rule of vitality change), the distinction between QH and QL is the yield electric control Wß. The control cycle is exceptionally comparable to the control cycle of a motor, so a thermoelectric control plant can be considered a one-of-a kind warm motor [25]. The thermoelectric execution is communicated by condition 5. [26]

$$Z = \frac{a^2}{k\,R} \tag{5}$$

Where: Z is the dimensionless figure of merit thermoelectric, α is the regression coefficient of:

$$\alpha = \frac{\Delta V}{\Delta T} \tag{6}$$

R is the electrical resistivity, and K is the total thermal conductivity; The merit number can be changed to dimensionless by multiplying by T (the average absolute temperature of the hot and cold plates of the thermoelectric module, K), namely:

$$ZT = \frac{\propto^2 T}{kR} \tag{7}$$

$$T = \frac{TH+TL}{2} \tag{8}$$

The condition $\frac{a^2}{R}$ is called the factored power. In general, thermoelectric power plants exhibit low efficiencies due to the current thermoelectric materials' relatively small dimensions (ZT = ≤ 1). The thermoelectric work process of converting heat into electrical energy is shown in Fig 4.

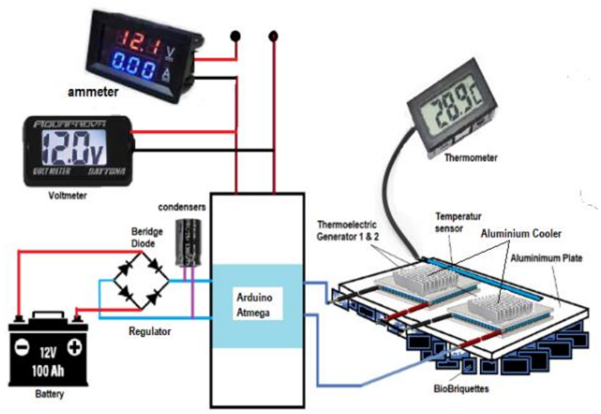

Fig 4. Heat conversion process electricity using a thermoelectric

3. Results and Discussion

The results of testing the water content, calorific value, and burning rate of biobriquettes from coconut shells are as shown in “Table 1”.

Table 1. Test results for water content, calorific value, and burning rate of coconut shell biobriquettes

Massa Sample (gr)	tapioca glue (gr)	Sago Glue (gr)	moisture content (%)	calorific value (cal/gr)	burning rate (gr/sec)
200	5	5	6.39 %	5362.7	0.237
300	10	10	7.15 %	5743.2	0.462
400	15	15	7.47 %	6523.3	0.663

The results of testing the conversion of the calorific value of coconut shell biobriquettes into electrical energy using thermoelectric in several samples are shown in “Table 2, Table 3, and Table 4”.

Table 2. conversion of the calorific value of coconut shell bio briquettes into electrical energy for a mass of 200 gr.

No	Mass of Sample (gr)	hot side (ºC)	Cold side (ºC)	ΔT (T2 – T1)	Time (minute)	Voltage (Volt)	Current (Ampere)	Power (Wh)
1		44	28	14	2	2	0.13	0.25
2		46	28	16	3	2.4	0.20	0.58
3		53	31	20	6	3	0.23	0.73
4		55	32	21	7	3.6	0.41	1.64
5		58	34	22	9	4.4	0.4	2.30
6		61	34	25	11	5.7	0.70	4.19
7		63	35	26	12	6	0.72	5.19
8	Coconut shell 200 grams	71	35	34	14	7.7	0.90	7.27
9		76	35	39	16	9	1	10
10		84	36	46	18	12	1.3	17.04
11		92	37	53	20	14	1.4	23.50
12		105	39	68	24	15.8	1.65	26.05
13		196	41	157	26	18	1.72	30.87
14		205	44	163	28	20	1.76	35.21
15		230	47	186	30	23	1.83	42.08
Average		62,57 59.64	16,00 36.29	10,33 62.57	1,02 16.00	14,76 10.33	1.02	14.76

Table 3. conversion of the calorific value of coconut shell bio briquettes into electrical energy for a mass of 300 gr.

No	Mass of Sample (gr)	hot side (ºC)	Cold side (ºC)	ΔT (T2 – T1)	Time (minute)	Voltage (Volt)	Current (Ampere)	Power (Wh)
1		49	26	21	2	2	0.15	0.31
2		58	32	24	4	3.5	0.24	0.90
3		65	33	31	5	4	0.3	1.2
4		71	33	36	8	5.4	0.52	2.860
5		77	37	38	9	6.5	0.76	5.224
6		80	38	40	12	7.6	0.9	7.02
7		93	39	52	14	9.3	0.95	9.213
8	Coconut shell 300 grams	93	40	53	15	12.5	1.2	15.22
9		103	41	60	18	17	1.3	23.20
10		208	43	162	20	20	1.6	35.6
11		235	43	190	21	24	1.8	46.6
12		50	26	21	2	2	0.15	0.31
13		60	32	24	4	3.3	0.24	0.90
14		65	33	30	5	4	0.3	1.2
15		71	33	36	8	5.0	0.53	2.860
Average		62,57 91.87	16,00 35.27	10,33 54.53	1,02 9.80	14,76 8.41	0.73	10.17

Table 4. conversion of the calorific value of coconut shell bio briquettes into electrical energy for a mass of 400 gr.

No	Mass of Sample (gr)	hot side (°C)	Cold side (°C)	ΔT (T2 – T1)	Time (minute)	Voltage (Volt)	Current (Ampere)	Power (Wh)
1	Coconut shell 400 grams	54	33	20	2	3.4	0.2	1
2		56	34	21	4	3.8	0.31	1.27
3		63	35	27	6	4.2	0.3	1.71
4		70	37.7	32.1	8	5.6	0.5	3
5		80	38.6	42.2	10	7.4	0.77	5
6		82	38	43	12	8.5	0.88	7.652
7		93	40.8	54	14	12	1	12
8		135	41.4	94.4	16	17.7	1.2	23.13
9		193	41	151	18	21	0.94	20.8
10		226	42.4	184.4	20	22	2.4	57.4
Average		62,57 105.2	16,00 38.19	10,33 66.91	1,02 11	14,76 10.56	0.85	13.29

Graphs of the effect of temperature changes on voltage, current and electric power, as shown in Fig. 5.

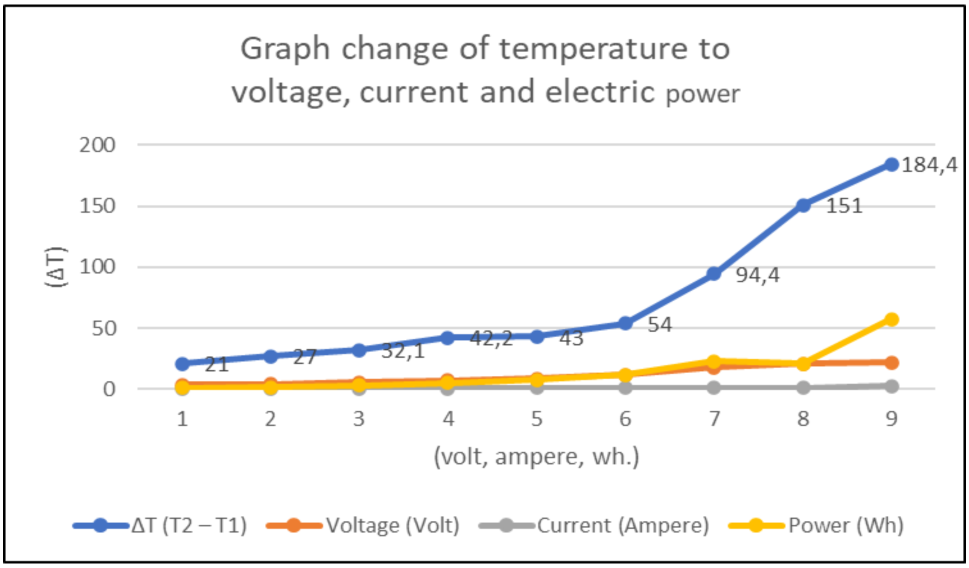

Fig 5. Effect of temperature on voltage, current and electric power

4. Conclusion

Based on the results of the study, it can be concluded that coconut husk is a material that can produce good quality electrical energy. Before being used as an energy source, coconut shell is first processed into bio-briquettes, which must have a low moisture content and a long burning time in order to achieve a high temperature.

The energy conversion process using thermoelectricity shows that coconut shell bio-briquettes with a mass of 200, 300 and 400 grams can produce an average of 13.35 Wh of electrical energy. To obtain more electrical energy, more bio-briquettes should be produced and the texture of the bio-briquettes should be smoother and denser. The thermoelectric energy conversion device should be designed for a larger capacity.

Acknowledgements

The author would like to thank the Institute for Research and Community Service, State University of Gorontalo, which has approved and provided support for this research.

References

[1] D. Hernández and E. Siegel, Energy insecurity and its ill health effects: A community perspective on the energy-health nexus in New York City, Energy Research & Social Science, international journal Volume 47, January 2019, Pages 78-83. (article)

[2] F. Martins, C. Felgueiras, M. Smitkova, and N. Caetano, Analysis of Fossil Fuel Energy Consumption and

Environmental Impacts in European Countries, Energies 2019, 12, 964; doi:10.3390/en12060964

[3] F. Perera, Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist, International Journal Environ Res Public Health, 15(1): 16, Published online Dec 23, 2017. (article)

[4] A. Boretti, Continued fossil fuel emissions and cognition impairment, International Journal of Global Warming, Published 8 May 2021, DOI:10.1504/ IJGW.2021.10037785 (article)

[5] V. Vedanarayanan, Chirag Vibhakar, A. Sujaatha, Jiten K. Chavda, M. Karthik, P. V. Pramila, Ishwarya Komalnu Raghavan, "Utilization of Sustainable Resources for Promoting Energy Efficiency in Environment Using Smart Technologies", International Journal of Photoenergy, vol. 2022, Article ID 6711300, 9 pages, 2022. https://doi.org/10.1155/2022/6711300. (article)

[6] C. Wang 1, H. Tibo and D.H. Duong, Renewable Energy Utilization Analysis of Highly and Newly Industrialized Countries Using an Undesirable Output Model, Energies 2020, 13(10), 2629; https://doi.org/10.3390/en13102629. (article)

[7] P. Kumah, P. A. Sowah, A.R. Adam, Emerging Energy Sources for Sustainable Power Generation: An Overview, Engineering and Technology Journal. Vol 8 No. 3, 6 March 2023. DOI: https://doi.org/10.47191/etj/v8i3.02 (article)

[8] Asian Development Bank, Indonesia Energy Sector Assessment, Strategy, And Road Map Update December 2020. DOI: http://dx.doi.org/10.22617/TCS200429, (books)

[9] E. Wahyuni & H. Ardiansyah, Indonesia's National Strategy and Commitment towards Transition to Renewable Energy, Overseas Indonesian Student's Association Alliance & BRIN Publishing 2022. (book)

[10] M. Langhof and Andrea S., 13 years of biomass production from three poplar clones in a temperate short-rotation alley cropping agroforestry system, Biomass and Bioenergy. Vol 175 (2023). Available online Jun 9 2023. (Book Publishing) DOI: https://doi.org/10.1016/j.biombioe.2023.106853

[11] R. Kandpal, R. Singh, Renewable Energy Sources – A Review, IOP SCIENCE ©ECS-The Electrochemical Society ECS Transactions, Volume 107, Number 1, 2022. DOI 10.1149/10701.8133ecst (prosiding)

[12] P.D.C. Sanchez, M.M.T. Aspe, K.N. Sindol, An overview on the production of bio-briquettes from agricultural wastes: methods, processes, and quality, Journal of Agricultural and Food Engineering 1 (2022) 0036, DOI: http://doi.org/10.37865/jafe.2022.0036. (article)

[13] P.D. Sanchez, M.M.T. Aspe, K.N. Sindol, An Overview on the Production of Bio-briquettes from Agricultural Wastes: Methods, Processes and Quality, Journal of Agricultural and Food Engineering 1 (2022) 0036, DOI: http://doi.org/10.37865/jafe.2022.0036 (article)

[14] A. Tamilvanan, Preparation of Biomass Briquettes using Various AgroResidues and Waste Papers, Journal of Biofuels, Vol. 4 Issue 2, July-December 2013 pp. 47-55, (article) DOI: 10.5958/j.0976-4763.4.2.006. (article)

[15] V.A. Pinchuk, T.A. Sharabura, A.V. Kuzmin, The effect of water phase content in coal-water fuel on regularities of the fuel ignition and combustion, Fuel Processing Technology, Volume 191, August 2019, Pages 129-137. https://doi.org/10.1016/j.fuproc.2019.04.011

[16] F. Inegbedion and E. Ikpoza, Estimation of the Moisture Content, Volatile Matter, Ash Content, Fixed Carbon and Calorific Values of Rice Husk Briquettes, Proceedings of the International Conference on Industrial Engineering and Operations Management Nsukka, Nigeria, 5 - 7 April 2022. (proceedings)

[17] M.L. Ramadhan, J. Carrascal, A. Osorio and J.P. Hidalgo, The effect of moisture content and thermal behaviour on the ignition of Eucalyptus saligna leaves, International Journal of Wildland Fire 30(9) 680-690, 21 June 2021, https://doi.org/10.1071/WF20069

[18] D. A. da Silva, A.L.S. Hansted, G.T. Nakashima, E.R.D. Padilla, J.C. Pereira, and F.M. Yamaji, Volatile matter values change according to the standard utilized, Research, Society and Development, V. 10, No. 12, e291101220476, 2021, (article) DOI: http://dx.doi.org/10.33448/rsd-v10i12.20476

[19] G.S. Kumar, C.J. Rao, S.K. Madhavi, Evaluation Of Calorific Value Of Bio-Briquette, International Journal of Research in Engineering and Technology, Volume: 05 Issue: 09, Sep-2016, (article) DOI: http://ijret.esatjournals.org

[20] H. Jinqiao, C. Leng, B. Liu, Z. Chen, L. Zhenlin, Analysis of flame characteristics of low calorific value gas diffusion combustion under the action of thermal dynamics, Combustion Theory and Modelling Volume 24, 2020 - Issue 5, (book) https://doi.org/10.1080/13647830.2020.1793001

[21] Mohammed T.I. and Olugbade T.O., Burning Rate of Briquettes Produced from Rice Bran and Palm Kernel Shells, International Journal of Material Science Innovations Volume 03, Issue 02, Pages 68-73, 2015, (article)

[22] Taylor, R.A. "Applicability of Nanofluids in High Flux Solar Collectors". Journal Of Renewable And Sustainable Energy 3, 023104. 2011. (article)

[23] Khairil, I. Arwiyan, Akhyar, S. Sofyan, Fundamental Study on Combustion Characteristics of Bio-briquette as Alternative Fuels for Domestic Coffee Stove, IOP Conference Series: Earth and Environmental Science, Volume 1121, 2022 8th International Conference on Environment and Renewable Energy 25/02/2022 - 27/02/2022 Hanoi, Vietnam (prosiding)

[24] S.B. Riffat and Xiaoli Ma, "Thermoelectrics: A review of present and potential applications". Applied Thermal Engineering 23 (2003) 913–935. (article)

[25] Sahin, Ahmet Z. Yilbas, Bekir S.. "Performance analysis of a thermoelectric power generator under volumetric constraint". Transactions of the Canadian Society for Mechanical Engineering, Vol. 40, No. 1. March 2016. (article)

[26] N. Jaziri, A. Boughamoura, J. Müller, B. Mezghani, F. Tounsi and M. Ismail, A comprehensive review of Thermoelectric Generators: Technologies and typical applications, Energy Reports Volume 6, Supplement 7, December 2020, Pages 264-287. (article).