2022 年度 試験研究助成 一覧

＜インドネシア＞

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1	インドネシア大学 UNIVERSTIAS INDONESIA	Techno-Enviro-Economic Assessment of Floating Photovoltaic to Hydrogen Technology on the Jatiluhur Reservoir for the Hydrogen Injection into Natural Gas Pipeline Network 電力デマンド対応のために天然ガスパイプラインへの水素注入を行うジャティルフル ダムにおける浮体式太陽光発電システムの技術・環境・経済性評価	Rahma Muthia. S.T., M.Sc., Ph.D.
2		Development of g-C3N4-based Photoanodes for Photoelectrochemical Hydrogen Production Utilizing Pharmaceutical Waste as Anodic Sacrificial Agents 医薬品廃棄物をアノード剤とする光電解水素製造におけるグラフィティック・カーボンナイトライド系光アノードの開発	Muhammad Ibadurrohman, Ph.D.
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2		Carbon Sequestration and Tree Community's Dynamics during 10 Years of Permanent Plot Monitoring at Mount Rinjani リンジャニ山 10 年モニタリングデータの炭素隔離と森の群生動態について	Dr.Endah Sulistyawati
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3		Design and Construction an Integrated Water Quality and Weather Monitoring System Based on Renewable Energy 再生可能エネルギーによる水質・気象総合監視システムの設計・構築	Dr. Alvin Fathikunnada, S.T.
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＜マレーシア＞

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3		Incorporation of Cloisite15A in the Polysulfone Matrix Membrane via Phase Inversion Method for Humic Acid Removal フミン酸除去のための相反転法によるポリスルホン基材膜への強化剤クロイサイト 15A の導入	Mohamed Afizal Bin Mohamed Amin
4		Detection of Power Line Insulator Defects on Power Transmission Line Based on an Improved Faster Region-Convolutional Neural Network and ResNest Algorithm 画像分類における改良型高速化領域畳込みニューラルネットワークとResNestアルゴリズムを利用した送電線碍子の欠陥検出	Dr Annie Anak Joseph
5		The Behaviour of Dewatered Sewage Sludge and Fly Ash Mix as a Potential Recycling Product. 下水汚泥と石炭発電灰の様々な組成の混合物を埋立廃棄物被覆材として利用するための安全性評価	NOR AZALINA BT ROSLI
6		INVESTIGATION OF MECHANICAL AND THERMAL PERFORMANCE OF RAW LOCAL BAMBOOS IN SARAWAK AS CONSTRUCTION MATERIALS サラワク産の竹の建材としての力学的・熱的性能の検討	Dr.MOHAMAD ISKANDAR BIN JOBLI

FINAL REPORT

OSAKA GAS FOUNDATION OF INTERNATIONAL

CULTURAL EXCHANGE

Year 2022/2023

TECHNO-ENVIRO-ECONOMIC ASSESSMENT OF FLOATING PHOTOVOLTAICS-TO-HYDROGEN TECHNOLOGY ON THE JATILUHUR RESERVOIR FOR THE GREEN HYDROGEN INJECTION INTO NATURAL GAS PIPELINES NETWORKS

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UNIVERSITAS INDONESIA

DEPOK

2023

Research Summary

This study proposes a new concept of renewable power-to-gas process by the utilization of floating photovoltaic-to-hydrogen technology on the Jatiluhur reservoir — the largest reservoir in Indonesia — in West Java province. The proposed floating photovoltaic system generates green electricity that will be utilized for two purposes: (1) to produce green hydrogen, and (2) to send excess electricity to the existing grid. The proposed concept in this study is to utilize and inject yielded green hydrogen into existing natural gas pipeline networks in West Java. The blending of green hydrogen and natural gas brings a notable impact in decarbonization by lowering the utilization of pure natural gas. The proposed integrated concept potentially brings a significant contribution in achieving the national energy mix strategy declared by the Indonesian government. Technical, environmental and economic aspects of the application of the proposed technology will be assessed in this study and recommendations regarding the technology implementation will be provided as the outcome this research.

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1. Proposal Summary

In line with the UN SDGs, the Indonesian government has declared an ambitious plan to escalate the contribution of renewable energy in the Indonesian energy mix strategy. According to the General Plan of National Energy (RUEN) of Indonesia, the targeted solar photovoltaic (PV) plants capacities by 2025 and 2030 are 6.5 GW and 14.2 GW, respectively (Anon, 2017). The RUEN was extensively detailed further in the latest Indonesia's 2019 – 2028 Electricity Procurement Plan (RUPTL) launched in 2019, which regulates a minimum target of 1 GW solar power plant development per year until 2028 (Ruiz et al., 2020). This ambitious target was set considering a big potential of the energy utilization from solar power in Indonesia, with the national average global horizontal irradiation of 4.80 kWh/m^2/day that could provide approximately 500 GW of energy (Veldhuis and Render, 2015; Tampubolon, et al., 2019).

The great potential of the utilization of solar photovoltaic technology is, however, hindered by its limitation on the requirement of massive spaces for its installation. Recently, floating PV emerges as a new and attractive form of PV technology, in which it is installed on water bodies such as lakes and reservoirs instead of on spacious lands. This feature offers a significant solution for the application of PV technology. Currently, there is one floating PV system with the capacity of 145 MW being installed on the Cirata reservoir in West Java province (Matich, 2020). The floating PV is expected to be commercially operated since the end of 2022 for supplying electricity to about 50,000 houses.

With an extensive plan of the Indonesia's RUPTL, the Indonesian government targeted to have 60 floating PV systems installed and operated by 2030 (Matich, 2020). The potential of the floating PV installation on the largest reservoir in Indonesia — the Jatiluhur reservoir in West Java province — will be evaluated in this research. The reservoir has the surface area of about 83 km^2, which are, to date, used for floating net ponds and the generation of hydroelectric power.

This study proposes the conceptual design of green hydrogen production for industrial end users, by utilizing a floating photovoltaic system. To the best of our knowledge, this is the first integrated study evaluating both technical and economic aspects of green hydrogen generation, transportation and blending with natural gas for end users. This work addresses the challenge of supplying a continuous flow of green hydrogen that is typically demanded by industrial end users. The presented results highlight the techno-economic design viability that can be applied to pave the way for the energy transition.

2. Research Description

The new concept of floating photovoltaic-to-hydrogen technology on the Jatiluhur reservoir and the injection of green hydrogen into natural gas pipeline networks in West Java promises a remarkable increase in the utilization of renewable energy, which is in line with the targets declared by the Indonesian government. How feasible and attractive is the implementation of this technology? This study aims to answer this research question by the assessment of technical and economic aspects of the proposed new concept. The objective of this research is to fulfil the following expected outcomes:

1. an estimated potential capacity of the floating PV system installed in the Jatiluhur reservoir,
2. a projection of the amount of green hydrogen produced by using a proton exchange membrane electrolyzer cell, and
3. recommendations of the technology implementation as the results of technical viability and economic feasibility analyses carried out in this research.

3. Methodology

Figure 1 depicts the schematic system proposed in this study. The proposed system consists of floating photovoltaic modules installed on the Jatiluhur reservoir, operating devices including electrolyzer and batteries units placed next to the reservoir, and a hydrogen pipeline system delivering hydrogen to the entrance gate of the Jababeka industrial estate – a centralized industrial area in West Java. While, excess electricity generated during the day time is bought by the state-owned electricity company, Perusahaan Listrik Negara (PLN) for its utilization by residents.

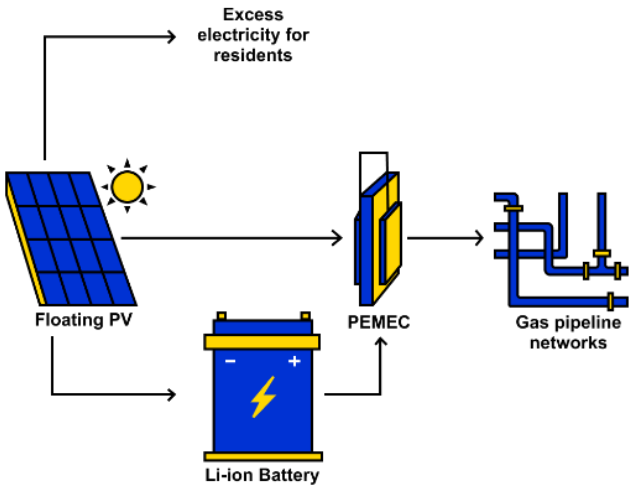

Figure 1. The schematic system proposed in this study

Figure 2 provides the spatial connections of the system's elements. The Jatiluhur reservoir – the largest reservoir in Indonesia – is located on Java Island, which is one among five big islands in Indonesia. The reservoir has the surface area of 83 km^2 (Hidayati et al., 2018), and currently it serves several activities for different purposes including fish ponds, water irrigation and hydroelectric power generation. Disregarding the occupied water spaces for those existing activities and considering a relatively distant space to the hydroelectric power generation location (shown by the triangle marker in Figure 2), it was interpreted from the Google Earth engine that there is a maximum surface area of 5 km^2 on the Jatiluhur reservoir that can be utilized for the floating PV modules installation. Thus, this value becomes the upper limit of the available space considered in this study. The ratio of the estimated maximum surface area to the total surface area of the Jatiluhur reservoir, i.e., 0.06, is within the practical range of the FPV installation on water bodies, which is within 0.01 – 0.1 (Kumar et al., 2021).

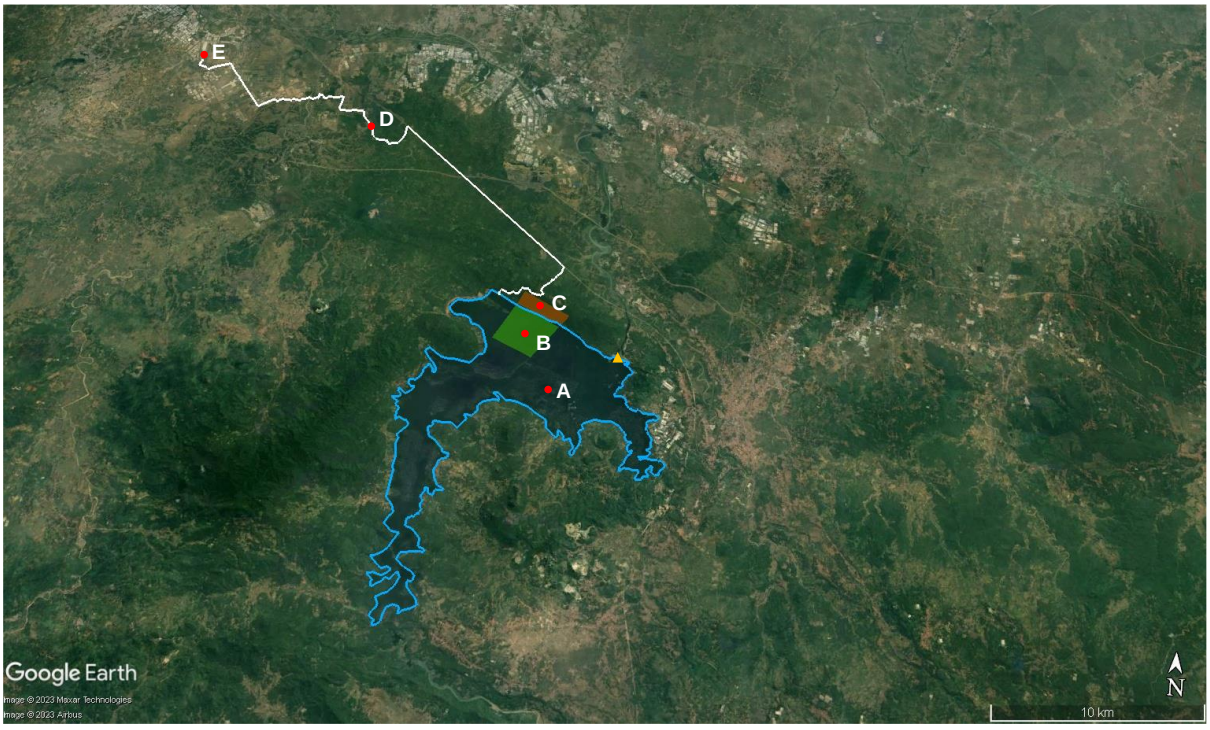

Figure 2. The map of the assessed system, (a) the Jatiluhur reservoir, (b) the potential space for the FPV installation, (c) the potential space for supporting facilities, (d) hydrogen pipeline route, and (e) final hydrogen delivery point for industrial end users

The assessment in this study was initiated by the estimation of the green hydrogen demand for the purpose of blending with natural gas. Then, the simulation work in the Aspen Plus v.12.1 process simulator was performed to calculate the amount of power required to operate the

electrolyzer unit for producing green hydrogen. Such power requirement became the input information for the simulation in the HOMER Pro v.3.14.5 software to obtain the FPV capacity and the number of batteries. Subsequently, the number of PV modules and the required surface area on the Jatiluhur reservoir were quantified. The calculated area was then compared with the maximum available surface area defined earlier. Next, the simulation work in the Aspen Plus v.12.1 process simulator was carried out to model the green hydrogen transportation via the pipeline system. Finally, the simulation work was done to evaluate the hydrogen-natural gas blending effects using the Aspen Plus v.12.1 process simulator.

4. Results

The process flowsheeting for the PEM electrolysis was obtained from the simulation in Aspen Plus by adapting those suggested by Zaccara et al. (2020). The flowsheeting, as shown in Figure 3, can be divided into four sections, i.e.: (1) process pre-conditioning, (2) stack, (3) cathode, and (4) anode sections. In the process pre-conditioning section, the pressure and temperature of the water inlet were adjusted to the specified operating conditions at 80 bar and 90 °C assuming that the fresh water was under atmospheric pressure at the ambient temperature. Then, the conversion of water to hydrogen and oxygen occurred in the stack section (an RSTOICH reactor in Aspen Plus) obeying the overall reaction mechanism given in in Eq. (3). While, the rest of the process sequence shown in Figure 3 depicts the cathode and anode sections in the PEM electrolyzer.

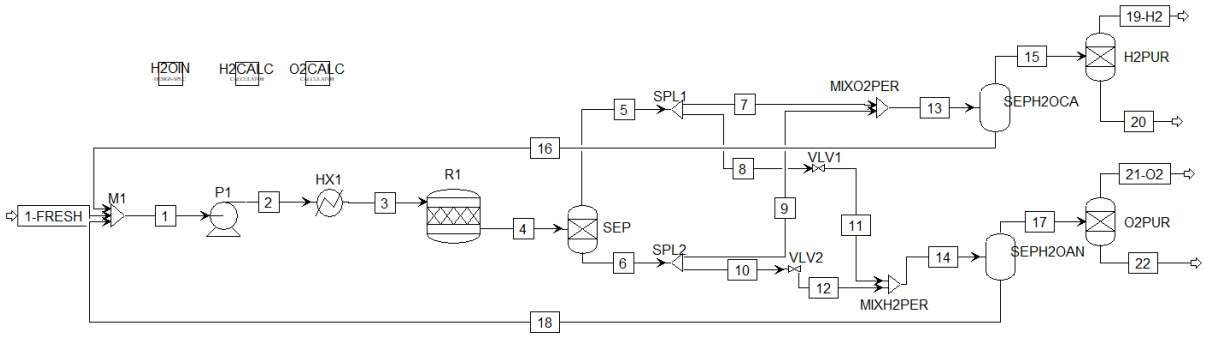

Figure 3. The PEM electrolyzer flowsheeting

The process performance of the PEM electrolyzer obtained in this work, as listed in Table 1, is then compared with that given in the literature, in which the attained values are close to those suggested by Zaccara et al. (2020). Besides, they are within the practical ranges that are commonly

encountered in the PEM electrolysis application. Those practical values were achieved with the PEMEC active area of 0.3 m^2. The input of the active area to Eqs. (4) – (5) suggested by Zhang et al. (2012) results in the power of 40.23 MW, which becomes the base for the determination of the electricity that needs to be continuously supplied by the FPV system.

Table 1. PEM electrolyzer process performance

Parameter	Value	
	This work	Zaccara et al. (2020)
Required energy (kWh/kg H_2)	54.57	54.80
Water inlet (kg H_2O/kg H_2)	9.39	9.80
Efficiency (%)	61.1	62.6

Figure 4 displays the system configuration simulated in HOMER Pro. Electricity produced from the floating PV system passes to the PEMEC in the direct current form, while it is also simultaneously stored in the battery system during the day time to enable a continuous electricity supply for PEMEC despite the solar PV intermittency. Considering an hourly electricity load of 40.23 MW during the weekdays and weekends for the PEMEC and also the random variabilities of 5% for day-to-day and timestep, the total estimated demand load for the PEMEC is 965.63 MWh/day.

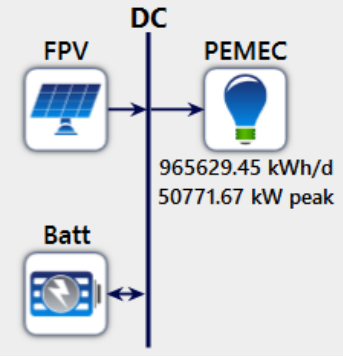

Figure 4. Simulation in Homer

The design architecture, as given in Table 2, consists of the FPV system with the capacity of 472,756 kW and 10,185 batteries with the nominal capacity of 100 kWh. With the suggested design, the electricity demand can be provided from a 100% renewable resource, i.e., solar energy. The simulation result suggests that the cycle charging strategy is more suitable for the proposed system due to the continuous electricity demand behavior during the day and night times. There

are 1,390,459 PV modules required for the FPV installation, in which the value was obtained by dividing the capacity of the FPV system over the module rated capacity. Considering the dimension module of 77.20 inch x 39.10 inch and assuming that there is a 5-inches gap between two solar PV modules, the required water body space for the floating PV installation is 3.25 km^2, which is under the maximum value constrained.

Figure 5 depicts the system dispatch including the profiles of total electricity production and usage during a day. During the day from 00:00 to 23:00, the floating PV modules generated electricity, with its highest activity at 12:00. From 06:00 to 11:00, the battery charging takes place, while from 00:00 to 07:00 and 16:00 to 00:00 the battery discharging occurs supplying electricity for the PEM electrolyzer. While, surplus electricity is gained between 11:00 to 16:00 as the rate of battery charging already decreases, while the floating PV still gets sufficient sunlight producing electricity.

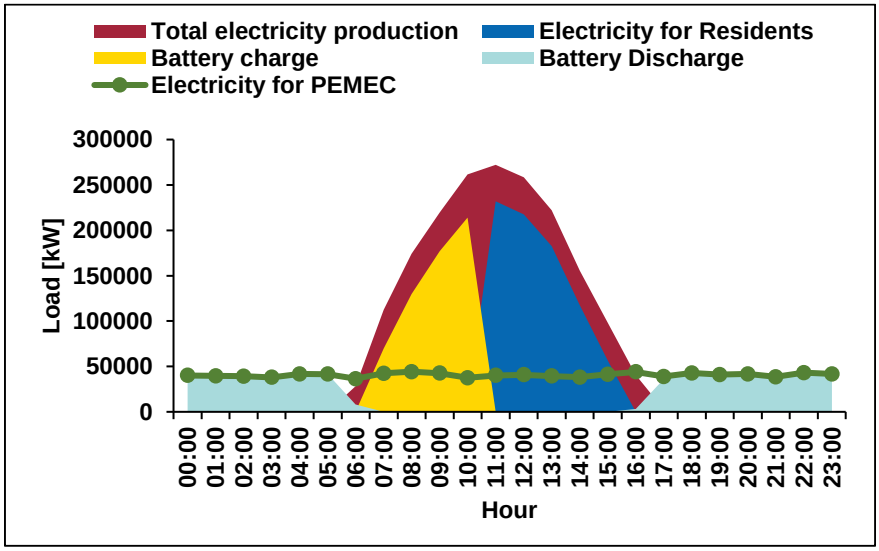

Figure 6 shows the simulation for the hydrogen and natural gas blending performed in Aspen Plus. The Wobbe indexes and the heating values of the gases obtained from the simulation are presented in Table 2. Those parameters for hydrogen and natural gas are similar to those presented in the literature (Roy at al., 2018; Zhao et al., 2019). While, both Wobbe indexes for pure hydrogen and natural gas are inside the standard Wobbe index bandwidth commonly specified for exit points of the gas transportation network for high calorific gas, which is from 47.0 to 55.7 MJ/m^3 (RVO, 2015). Based on the simulation, it is observed that the existence of hydrogen in the blended gas only results in a marginal decrease of the Wobbe index compared to that of natural gas, which is less than 2%. On the contrary, the addition of hydrogen leads to a slight increase of

the heating values on the mass basis by less than 2%, as the result of the smaller density of hydrogen compared to natural gas.

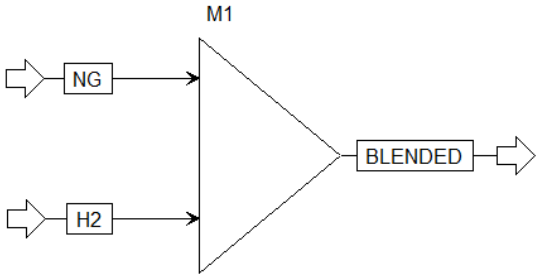

Figure 6. The hydrogen and natural gas blending simulation

Table 2. Wobbe indexes and heating value of gases before and after the gases blending

Parameter	Hydrogen	Natural gas	Blended gas
Wobbe index (MJ/m^3)	48.49	52.65	51.65
Lower heating value (MJ/m^3)	10.78	37.02	35.01
Lower heating value (MJ/kg)	119.83	47.00	47.68

The energy flow through the overall system is shown in the Sankey diagram demonstrated in Figure 7. To provide hydrogen for industrial end users with the energy equivalent to 590.00 MWh, the solar energy required is equivalent to 10,794.57 MWh. The major PV losses are caused by the solar PV nominal efficiency, which is typically encountered in the solar PV systems.

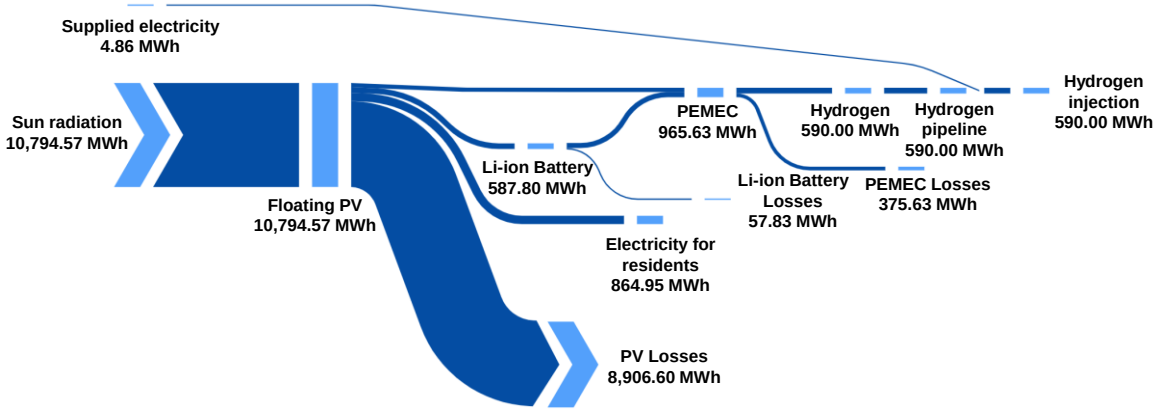

Figure 7. Sankey diagram of the proposed system

OUTPUT REPORT

MONITORING AND EVALUATION
OSAKA GAS FOUNDATION OF INTERNATIONAL CULTURAL EXCHANGE
2022/2023

Theme	:	Techno-economic analysis of green hydrogen production by the utilization of a floating solar photovoltaic system: a full chain of green hydrogen generation, transportation and blending with natural gas for industrial decarbonization
Researcher	:	Rahma Muthia, S.T., M.Sc., Ph.D.
Department	:	Chemical Engineering

Articles in SCOPUS

No	Title	International Journal	Level SCIMAGO (Q1/Q2/Q3)	*Progress Full Paper* (*not available/draft/submitted/Accepted /Published*)
1	Techno-economic analysis of green hydrogen production by the utilization of a floating solar photovoltaic system: a full chain of green hydrogen generation, transportation and blending with natural gas for industrial decarbonization	International Journal of Hydrogen Energy	Q1	Full draft (content checking and proofreading)

Depok, 29 Agustus 2023
Researcher

Rahma Muthia, S.T., M.Sc., Ph.D
NUP. 198908142021094001

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FINAL REPORT

OSAKA GAS FOUNDATION OF
INTERNATIONAL CULTURAL EXCHANGE
Year 2022/2023

DEVELOPMENT OF g-C_3N_4-BASED PHOTOANODES FOR PHOTOELECTROCHEMICAL HYDROGEN PRODUCTION UTILIZING PHARMACEUTICAL WASTES AS ANODIC SACRIFICIAL AGENTS

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Department of Chemical Engineering

Faculty of Engineering

UNIVERSITAS INDONESIA
DEPOK 2023

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1. PROPOSAL SUMMARY

While having all requirements as the most promising future fuel, hydrogen still holds the challenges in pursuing the best route towards sustainable production. The proposed research addresses the development of g-C_3N_4-based composites to be employed as photoanodes and photocatalysts for photoelectrochemical hydrogen production and photocatalytic degradation of pharmaceutical waste. In this study, g-C_3N_4 is used as a co-material along with α-Fe_2O_3 as photoanodes for hydrogen production and with TiO_2 as photocatalysts for degradation of ciprofloxacin. Combinations of the semiconductors are expected to establish heterojunctions that may facilitate charge carrier transfer and improvement in visible-light absorption capacity. The effects of precursor type of g-C_3N_4 and the sonication time during wet impregnation process onto α-Fe_2O_3 films will be investigated in terms of the characteristics and photoelectrocatalytic performance of the resultant films. The photoelectrochemical hydrogen production will be assessed under Xe lamp (white light illumination) in a three-electrode cell, while photocatalytic properties of the samples are done in terms of ciprofloxacin photo-assisted degradation. The use of ciprofloxacin is intended to model the waste stream from pharmaceutical waste. We hope that the proposed research may contribute to the technological advancement towards sustainable development goals.

2. RESEARCH DESCRIPTION

It is almost unanimously agreed upon that hydrogen possesses the most virtuous characteristics of future energy owing to its energy density and carbon-free features[1]. However, the efficient route of producting hydrogen has always been a standing challenge for decades. Photoelectrochemical technology is considered as one of the most promising routes for sustainable hydrogen production, as it exploits solar energy and aqua-based systems[2], two of the most abundant, renewable resources on Earth. Therefore, it is imperative to develop photoanodes that are capable of conducting efficient photoelectrochemical hydrogen production. Photoanode materials based on TiO_2 have been extensively studied in the past few decades owing to their excellent activity, chemical stability, and cost-effectiveness[3-5]. Despite these tremendous efforts, however, there remains a huge gap between recent development and commercial practicality of TiO_2-based photoelectrochemistry, mainly because of the inactivity toward visible light illumination[6-8].

In recent years, g-C_3N_4 has attracted huge interests as a promising alternative to TiO_2 due to its suitable band structure, capability of visible light absoprtion, non-toxicity, excellent stability,

and cost effectiveness[9-11]. Nevertheless, as in the case of any other materials, g-C_3N_4 is by no means free from drawbacks. The difficulties in fabricating high-quality films remain the main issue in the context of g-C_3N_4 photoelectrodes, which boil down to the fact that the material is extremely difficult to be dissolved or dispersed in common solvents[10]. The top-down approaches in preparing g-C_3N_4 films, such as doctor blade, silk-screen printing, or spin coating often result in films that are non-uniform, non-continuous and of poor adhesion to the substrate[10]. Inevitably, these issues have been reported to be the main factor of poor photoelectrochemical performances[12, 13]. Very recently, novel bottom-up techniques were introduced, namely thermal vapour condensation (TVC)[14-16], microcontact-printing-assisted access[17], solvothermal[18], and direct growth methods[19]. Among these methods, TVC was found to be quite promising as a synthetic route toward active, robust g-C_3N_4-based photoanode films[13, 14, 20-22]. The method is not only relatively simple but also allow good control of the film properties by adjusting the fabrication parameters (type and amount of precursors, annealing temperature and time, gas ambience, etc.).

On the pursuit of efficient photoelectrochemical hydrogen production, utilisation of g-C_3N_4 still spare many rooms for improvements[10]. Low conductivity and high rate of charge carrier recombination are often quoted as the bottleneck that limits the overall photoelectrochemical efficiency [10]. In order to circumvent these problems, several techniques to engineer g-C_3N_4-based materials have been proposed, such as metal doping (e.g. Ni, Cu, Fe) for better electron-hole separation[23-25], incorporation of highly conductive materials (such as graphene and MXenes)[26-28], defect engineering by creating crystal vacancies[29-31], and the formation of heterojunction structure with other semiconductors. Considering the aforementioned challenges and potential solutions, this research will focus on the development of g-C_3N_4 powders and films, combined with hematite and titania as photoanodes and photocatalysts for hydrogen production and removal of pollutants. The effects of types of precursors (i.e. melamine, urea, thiourea, dicyandiamide, or the combination thereof) will be investigated in terms of material characteristics and their photoelectrochemical performances. The photoelectrochemical assessments will be done under white light illumination in a three-electrode cell, while photocatalytic degradation of ciprofloxacin is done in a slurry photoreactor to model the treatment of pharmaceutical wastes. Through the approaches implemented in this research, we wish to contribute to the advancement of photoelectrochemical hydrogen production that is integrated with a waste management system.

3. METHODOLOGY

The synthesis of g-C_3N_4 powder was carried out by heating different types of precursors (melamine, urea, and dicyandiamide) in quantities of 50 grams each at a temperature of 500˚C for 5 hours. Furthermrore, α-Fe_2O_3 films were synthesized via a hydrothermal method. FTO glass pieces (1 x 5 cm and 2 x 5 cm) were immersed in a 1:1 ethanol and acetone solution, sonicated for 5 minutes, and dried. An α-Fe_2O_3 solution was formed by dissolving 2.03 g $FeCl_3$ and 1.556 g $NaNO_3$ in 50 mL deionized water. The solution was poured into a Teflon-lined autoclave, into which clean FTO glass was dipped. The autoclave was heated to 95°C, maintained for 5 hours, and then cooled. The resulting thin yellow film was rinsed, sonicated, and dried at 70°C for 2 hours. The film was calcined at 550°C in air for 1 hour to attain the desired hematite crystal structure before cooling to room temperature.

The synthesized α-Fe_2O_3 films were coated with g-C_3N_4 using the impregnation method. The process of coating g-C_3N_4 onto the α-Fe_2O_3 film involved the following steps. Firstly, 100 mg of the synthesized g-C_3N_4 powder was dissolved in 100 mL of isopropyl alcohol. The solution was then subjected to ultrasonication for 12, 16, 25, or 30 hours. The solution was centrifuged at 3000 rpm for 10 minutes. The top 30 mL of the solution, containing g-C_3N_4 thin nanosheets in the supernatant, was carefully pipetted. The formed g-C_3N_4 nanosheets were coated onto the surface of the α-Fe_2O_3 film using the impregnation method. The α-Fe_2O_3 film was immersed in 30 mL of the g-C_3N_4 nanosheet precursor for 15 minutes, then placed in an oven set at 90°C. This combination of settling and heating represented one cycle, and they are done for up to 9 cycles. The resulting α-Fe_2O_3/g-C_3N_4 photoanode was calcined at 350°C for 1 hour, followed by cooling to room temperature.

The photocatalyst composites of g-C_3N_4/TiO_2 were prepared by the following procedure. The synthesized variations of g-C_3N_4, amounting to 10 mg, were mixed with 1 gram of TiO_2 (P25) by stirring the mixture using a magnetic stirrer to achieve homogeneity. Each resulting mixture was dissolved in 40 mL of methanol within a glass beaker. The mixture of g-C_3N_4 and TiO_2 was subjected to ultrasonication by placing the glass beaker into an ultrasonic bath for a duration of 1 hour. The resulting solution was continuously stirred and heated to a temperature of 80 °C using a hot plate for 2 hours. Subsequently, the obtained g-C_3N_4/TiO_2 composites were subjected to a calcination process at 300 °C for 30 minutes.

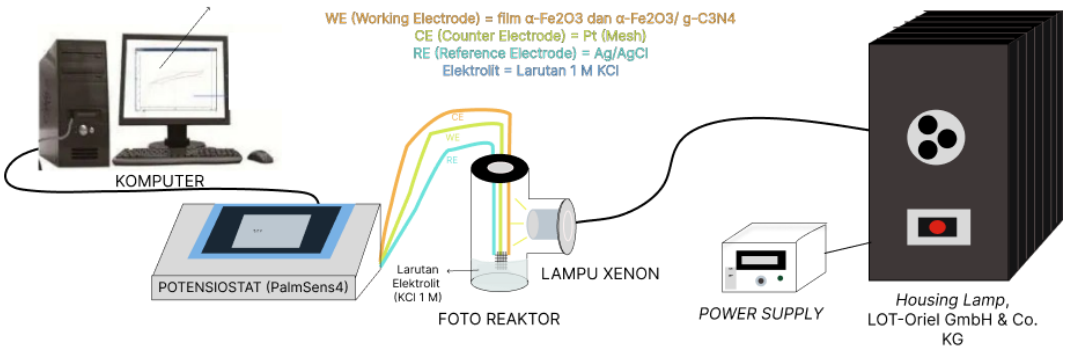

Figure 1. Schematic of the system for photoelectrolytic hydrogen production

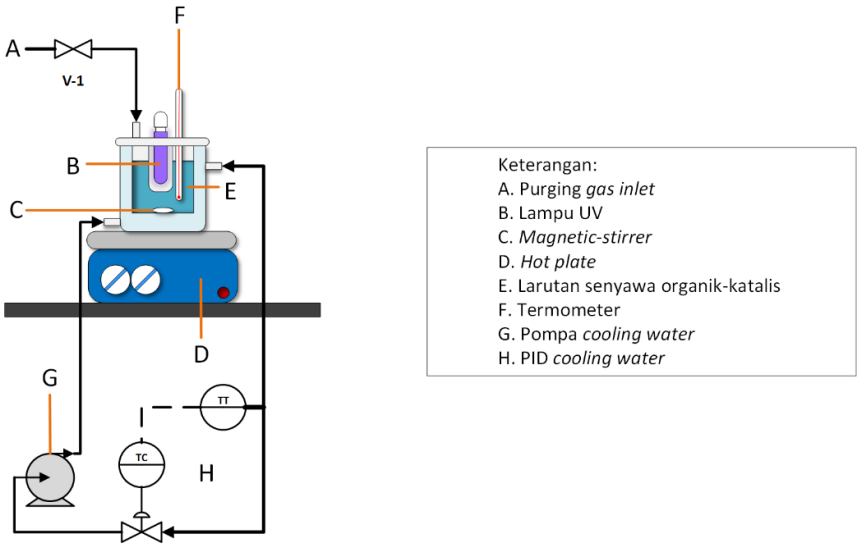

Figure 2. Schematic of the photoreactor system for photocatalytic degradation of ciprofloxacin

A series of characterisations were done to reveal the properties of the synthesized films. X-ray diffraction (XRD) analysis was conducted to identify the crystallinity of the samples. Fourier Transform Infrared (FTIR) spectroscopy was conducted to verify the functional groups. The optical properties of the films were measured using UV-Vis Diffuse Reflectance Spectroscopy (UV-Vis DRS). The morphology of the films was elucidated by means of Scanning Electron Microscope (SEM). The photoelectrochemical assessments of the films will be conducted under white light illumination (Xe lamp) in a three-electrode cell with 1 M KCl as the electrolyte (Figure 1), assigning the prepared film as the working electrode, Pt mesh as the counter electrode, and Ag/AgCl as the reference electrode. For photocatalytic degradation of ciprofloxacin, a schematic photoreactor is illustrated in Figure 2. A Pyrex reactor connected to an inert gas tube at the end is used in the reactor configuration for this photocatalytic degradation test of ciprofloxacin. This reactor configuration is equipped with a photon source

in the form of a 20W UV lamp and a thermometer to measure the temperature of the solution. The photoreactor was placed on a hot plate, stirred using a magnetic stirrer bar and connected to circulating cooling water through a pump.

4. INITIAL RESULTS

In Figure 3(a), the X-ray diffraction patterns of g-C_3N_4 samples synthesized from different precursors are depicted. g-C_3N_4 samples were prepared from urea (u), dicyandiamide (d), melamine (m), and that which is commercially obtained (k). The patterns reveal characteristic diffraction peaks of the graphite carbon nitride phase. Notably, peaks at $2\theta = 13°$ and 27.3° are observed, corresponding to diffraction from the crystal structure with Miller indices (100) and (002), respectively. The presence of the lowest peak at 13.1° signifies the tri-s-triazine unit, while the peak at 27.3° indicates the interlayer stacking of the aromatic segments. Meanwhile, Figure 3(b) depicts the Tauc plots generated from the UV-vis absorbance spectra of the g-C_3N_4 samples, revealing band gap approximates of around 2.6 – 2.7 for all samples.

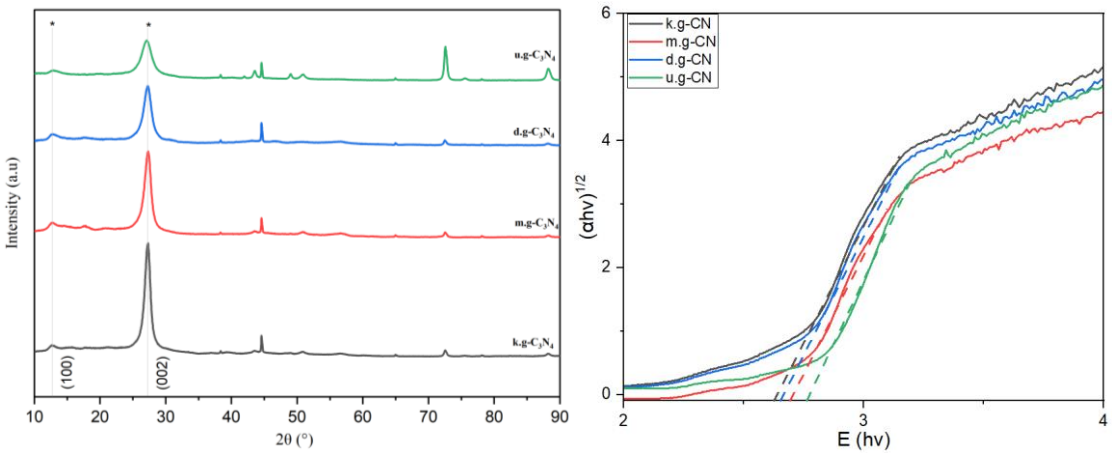

Figure 3. XRD patterns of g-C_3N_4 prepared from different precursors (a) and the Tauc plots processed from the UV-Vis absorbance spectra of the g-C_3N_4 samples

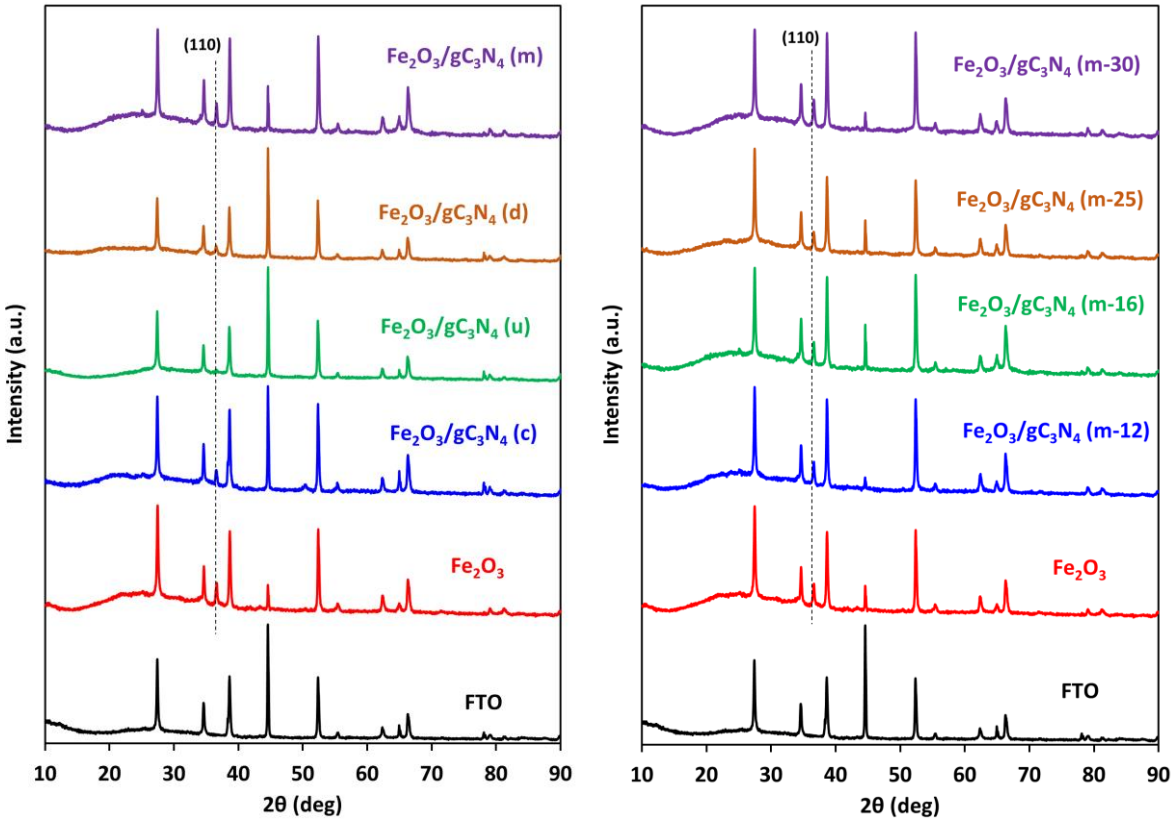

Figure 4. XRD patterns of α-Fe_2O_3/g-C_3N_4 photoanode composites with variation on g-C_3N_4 precursors (a) and sonication time during wet impregnation procedure (b)

Figure 4(a) illustrates the XRD patterns of the FTO substrate and Fe_2O_3/g-C_3N_4 photoanode films, namely α-Fe_2O_3, α-Fe_2O_3/g-C_3N_4(m), α-Fe_2O_3/g-C_3N_4 (d), α-Fe_2O_3/g-C_3N_4(k), and α- α-Fe_2O_3/g-C_3N_4(u). The presence of α-Fe_2O_3 is indicated by the appearance of the (110) peak at 36.6°, corresponding to hematite (α-Fe_2O_3 JCPDS No. 79-0007). In all α- α-Fe_2O_3/g-C_3N_4 films, only the FTO and α-Fe_2O_3 peaks are observed, while the g-C_3N_4 diffraction peak located at (002) 27.5° (JCPDS No.41-1445) (Zuo et al., 2021) is absent. This suggests that the crystallite size of g-C_3N_4 is too small to be detected by XRD, likely due to its low concentration. This may also indicate a good dispersion of g-C_3N_4 particles on the α-Fe_2O_3 surface (Fang et al., 2013). Figure 4(b) presents the XRD patterns of the composite samples with various sonication time during impregnation of g-C_3N_4 onto α-Fe_2O_3 films. The films are labelled α-Fe_2O_3/g-C_3N_4(m-12), α-Fe_2O_3/g-C_3N_4(m-16), α-Fe_2O_3/g-C_3N_4(m-25), and α-Fe_2O_3/g-C_3N_4(m-30) to denote the sonication time of 12, 16, 25, and 30 hours, respectively. The g-C_3N_4 used in this case was prepared from melamine. Similar to that perceived in Figure 2(a), no peak associated with g-C_3N_4 is observed due to low content and likely good dispersion.

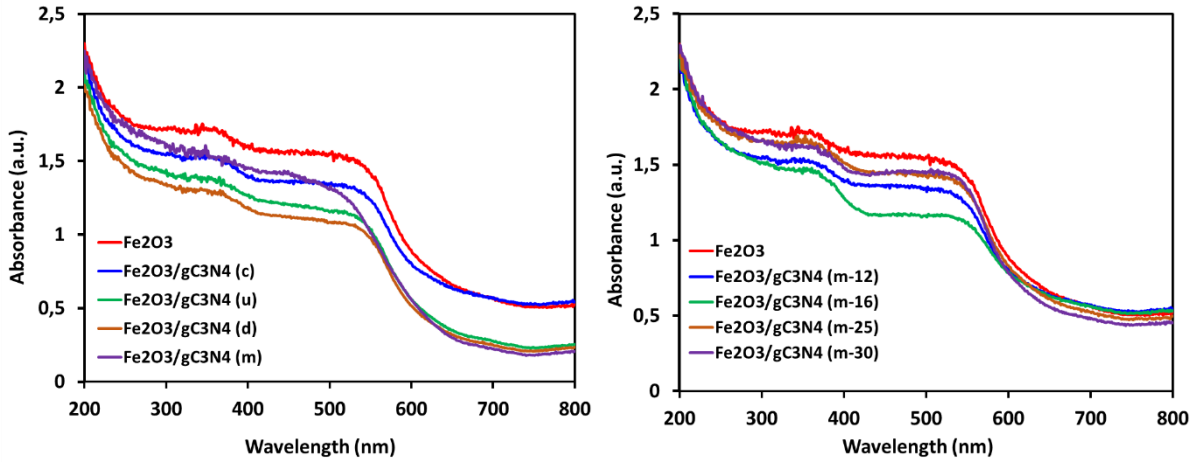

Figure 5. UV-vis spectra of α-Fe_2O_3/g-C_3N_4 photoanode composites with variation on g-C_3N_4 precursors (a) and sonication time during wet impregnation procedure (b)

The UV-Vis spectra depicted in Figures 5(a) and 5(b) represent the optical properties of α-Fe_2O_3 and its combination with g-C_3N_4 prepared from variations precursors. As shown in Figure 3(a), the samples α-Fe2O3, α-Fe_2O_3/g-C_3N_4(m), α-Fe_2O_3/g-C_3N_4(d), α-Fe_2O_3/g-C_3N_4(k), and α-Fe_2O_3/g-C_3N_4(u) each exhibited absorption edges at 676, 651, 649, 650, and 650 nm, respectively. Figure 3(b) shows the UV-vis absorbtion spectra of the photoanodes α-Fe_2O_3, α-Fe_2O_3/g-C_3N_4(m-12), α-Fe_2O_3/g-C_3N_4(m-16), α-Fe_2O_3/g-C_3N_4(m-25), and α-Fe_2O_3/g-C_3N_4(m-30) exhibited absorption edges at 676, 658, 651, 649, and 647 nm, respectively.

The FTIR spectra of α-Fe_2O_3/g-C_3N_4 composites with variation on g-C_3N_4 precursors are depicted in Figure 4(a). α-Fe_2O_3 exhibited two peaks around 469 and 542 cm^{-1} corresponding to Fe−O mode stretching. The FTIR spectrum of g-C_3N_4 displayed two distinctive vibration regions. The first region, approximately in 1210−1640 cm^{-1}, represents the characteristic stretching modes of C−N and C=N bonds in the aromatic ring structure of g-C_3N_4. The sharp peak around 810 cm^{-1} corresponds to the out-of-plane bending vibration of the heptazine ring. Similar characteristic signals were also observed for the α-Fe_2O_3/g-C_3N_4 samples with variation on sonication time during the wet impregnation process, as depicted in Figure 4(b).

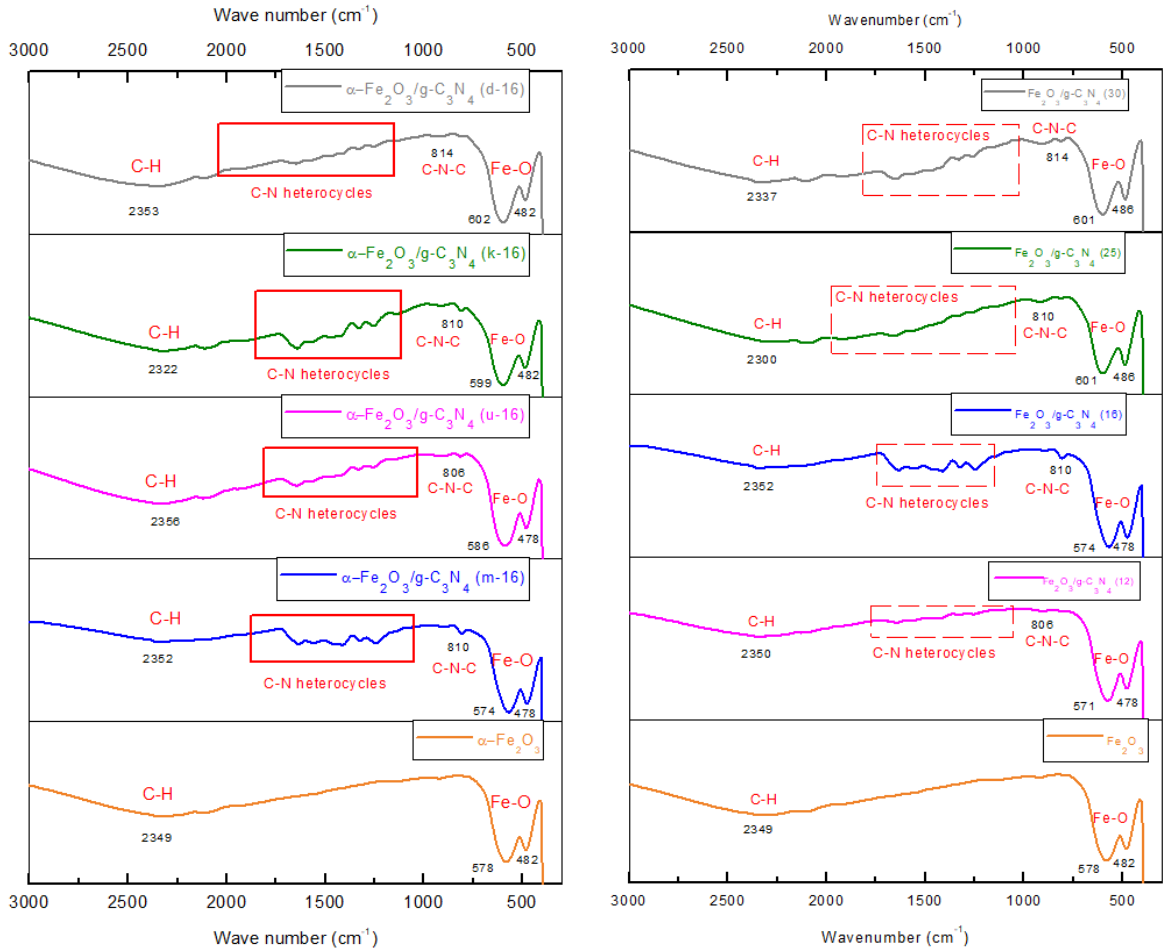

Figure 6. FTIR patterns of α-Fe_2O_3/g-C_3N_4 photoanode composites with variation on g-C_3N_4 precursors (a) and sonication time during wet impregnation procedure (b)

The surface morphology of α-Fe_2O_3 and α-Fe_2O_3/g-C_3N_4 films with varying sonication times can be observed in Figures 6(a) and 6(b). These films exhibit the formation of nanorods on the α-Fe_2O_3 compound. Based on the FE-SEM micrographs, the most well-formed nanorods are observed in the morphology of α-Fe_2O_3/g-C_3N_4(m-16), which also exhibits the best photoelectrolytic capability, as confirmed in the later section. Thus, the optimal sonication time for α-Fe_2O_3/g-C_3N_4 film synthesis is determined to be 16 hours. The respective lengths of nanorods in the films are, in the order of increasing sonication time, 252 nm, 342 nm, 718 nm, and 459 nm.

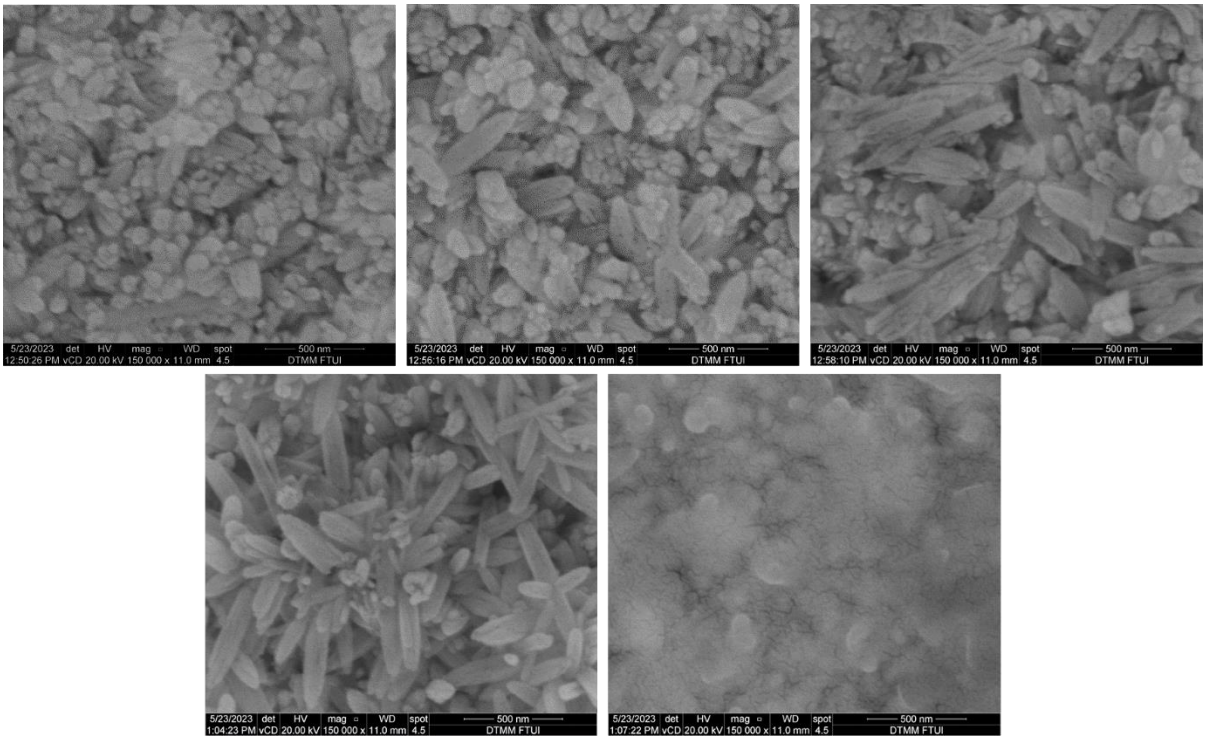

Figure 7. FE-SEM micrographs of α-Fe_2O_3/g-C_3N_4 photoanode composites with variation on sonication time during wet impregnation procedure

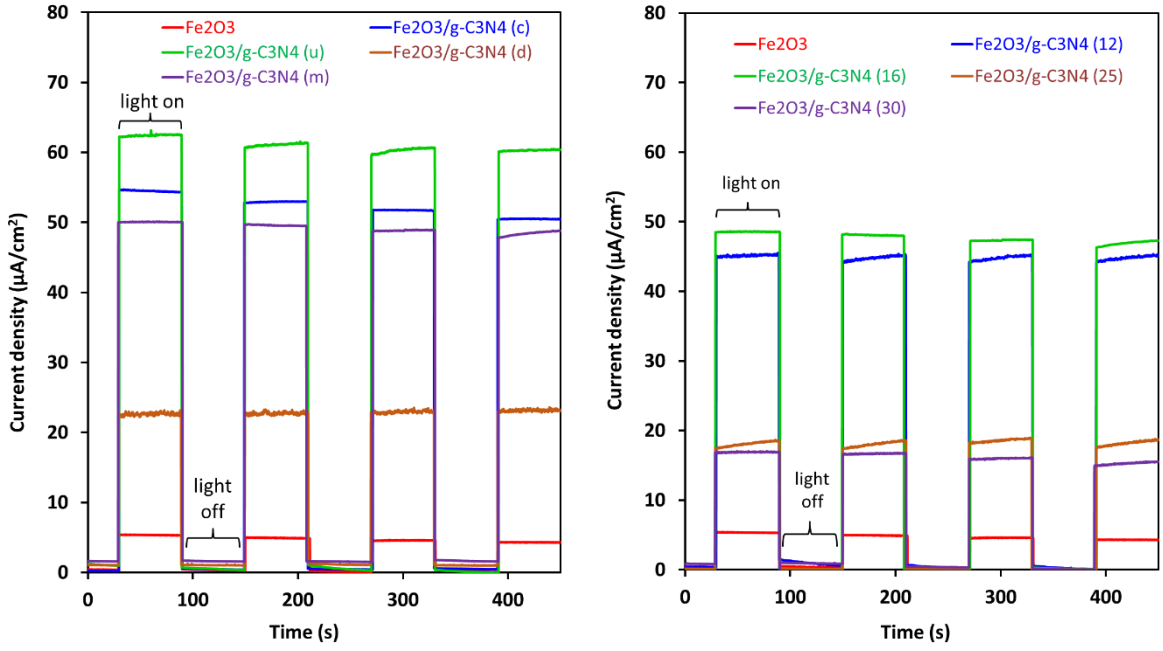

Figure 8. Light-chopped chronoamperometry of α-Fe_2O_3/g-C_3N_4 photoanode composites with variation on g-C_3N_4 precursors (a) and sonication time during wet impregnation procedure (b)

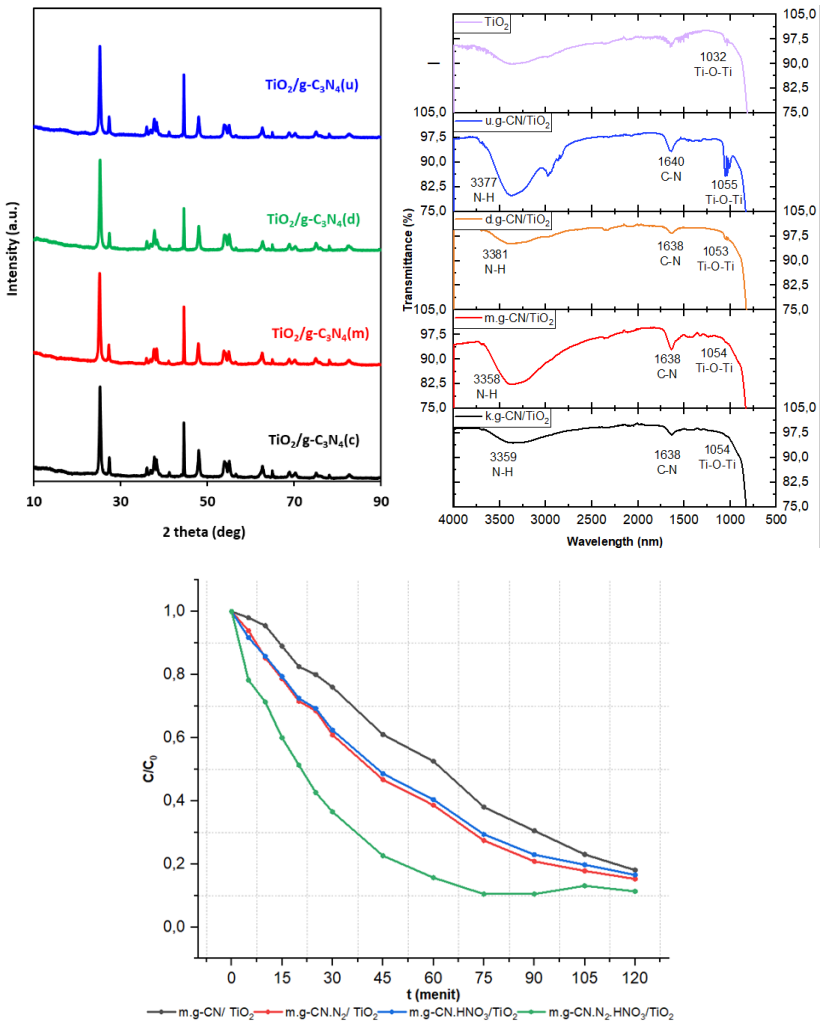

Figure 9. XRD patterns (a), FTIR spectra (b), and photocatalytic activities (c) of TiO_2/g-C_3N_4 photocatalysts with variation on g-C_3N_4 precursors on degradation of ciprofloxacin

Figure 6(a) illustrates the photocurrent density values for α-Fe_2O_3, α-Fe_2O_3/g-C_3N_4(m), α-Fe_2O_3/g-C_3N_4(d), α-Fe_2O_3/g-C_3N_4(c), and α-Fe_2O_3/g-C_3N_4(u) films, which are 1.26 μA/cm2, 12.10 μA/cm^2, 5.32 μA/cm^2, 13.61 μA/cm^2, and 15.30 μA/cm^2, respectively. The photoelectrolytic performance of the α-Fe_2O_3 film improved by 12 times when combined with g-C_3N_4 promoter at the optimal sonication time (16 h) and best precursor type (urea). This observation is supported by FE-SEM morphology, where the presence of the g-C_3N_4 promoter is most pronounced in the α-Fe_2O_3/g-C_3N_4(u-16) film, indicating that the promoter can effectively narrow the band gap energy due to its moderate band gap characteristics and appropriate electronic band structure. In this study, g-C_3N_4 was also used as a promotor for TiO_2 to make photocatalyst composites for the degradation of ciprofloxacin as a pollutant model for pharmaceutical waste. The XRD patterns, FTIR spectra, and photocatalytic activities of the composites with variation in g-C_3N_4 precursors are depicted in Figures 7(a) – 7(c).

OUTPUT REPORT

MONITORING AND EVALUATION

OSAKA GAS FOUNDATION OF INTERNATIONAL CULTURAL EXCHANGE

2022/2023

Theme	:	Development of g-C_3N_4-based Photoanodes for Photoelectrochemical Hydrogen Production Utilizing Pharmaceutical Wastes as Anodic Sacrificial Agents
Researcher	:	Muhammad Ibadurrohman, Ph.D (DIC)
Department	:	Chemical Engineering

Articles in SCOPUS

No	Title	International Journal	Level SCIMAGO (Q1/Q2/Q3)	*Progress Full Paper*
1	Photoelectrochemical and Photocatalytic Properties of g-C3N4/TiO2 Composites for Simultaneous Hydrogen Production and Waste Removal	Brazilian Journal of Chemical Engineering	Q3	Draft
2				
3				

Depok, 30 August 2023

Researcher

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NUP 198709182019093001

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Research Report

Osaka Gas Foundation of International Cultural Exchange

(OGFICE)

Research Title

The Synthesis of Corncob-based Hydrogel

Principal Investigator:

Dr. Dhewa Edikresnha, B.Eng., M.Si

Academic Unit

Research Division : Materials of Physics

Faculty/School : Faculty of Mathematics and Natural Sciences

INSTITUT TEKNOLOGI BANDUNG

November 2023

I. IDENTITY PAGE

1. Title : The Synthesis of Corncob-based Hydrogel
   Topic : Global environmental problems Research
   Period : November 2022 – November 2023

4.1. Principal Investigator :
   a. Full Name : Dhewa Edikresnha
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No	Name and Academic Rank	Field of Experties	Institution	Alocation of Time	
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2	Dian Ahmad Hapidin	Material Instrumentation	Institut Teknologi Bandung	10	12

4.3 Research Assistants/Students (mention names when available):

No	Name	Departement and NIM	Alocation of Time	
			Hrs/week	Months
1.	Halida R. Luthfianti	30221013	10	12
2.	William X. Waresindo	30221302	10	12
3.	Marathur Rodhiyah	20221302	10	12

5. Approved budget : Rp 90,384,000. 00

Head of Academic Unit

Prof. Ir. Wahyu Srigutomo, S.Si., M.Si., Ph.D
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Bandung, 22 November 2023
Principal Investigator

Dr. Dhewa Edikresnha., B.Eng.,M.Si
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I. EXECUTIVE SUMMARY

1. **TITLE OF RESEARCH** : **The Synthesis of Corncob-based Hydrogel**
2. **HEAD OF RESEARCH TEAM** : **Dr. Dhewa Edikresnha., B.Eng.,M.Si**
3. **TEAM MEMBERS** : **Prof.Dr.Eng. Khairurrijal, M.Si**
   Dr. Dian Ahmad Hapidin, M.Si
4. **OFFICIAL ADDRESS** : **Jl. Ganesha N0. 10, Bandung**

5. **EXTENDED ABSTRACT** :

Indonesia is one of the largest corn producers in the world, with a corn production of 14 million tons in 2023. Out of the total corn waste, corn cobs contribute at least 18% of the total waste. Corn cobs have several components, namely lignin (15.08%), cellulose (34.33%), and hemicellulose (20.17%). Cellulose is a natural polymer with several unique characteristic, including biocompatibility, biodegradability and non-toxicity. Furthermore, cellulose is structured of reactive hydroxyl groups that capable to absorb water due to its hydrogen-bonding propensity. This water absorption capability empowers cellulose as a potential matrix in hydrogel synthesis. Hydrogel is a three-dimensional network structure made from a polymer that can absorb water. Cellulose is extracted from corn cobs through delignification, bleaching, and acid hydrolysis processes. The content of cellulose after extraction process was 70.45%. Cellulose is then turned into a hydrogel using the freeze-thaw method to form a stable and non-toxic hydrogel structure. This study aimed to investigate the effects of adding different concentrations of NaOH, namely 2%, 3%, 4%, 5%, 6%, and 7%, on the physicochemical characteristics of cellulose hydrogels. The SEM images showed that the hydrogel with 3% NaOH concentration formed many cross-links and had the largest pore size. Additionally, that hydrogel exhibited the highest degree of swelling at 48 hours, with a value of 527.32 ± 8.41%, and showed the best compressive strength. As the NaOH concentration increased, the hydrogel experienced a higher weight loss. FTIR analysis confirmed the presence of cellulose groups in the extracted cellulose powder and also in the hydrogel, indicating the functional groups of cellulose. XRD results revealed that the cellulose powder was semi-crystalline with a crystallinity degree of 61.48%, while the cellulose hydrogel exhibited an amorphous structure. TGA testing showed that cellulose hydrogels with lower NaOH concentrations had better thermal stability compared to cellulose powder due to the formation of cross-links. As the NaOH concentration increased, the residue produced after combustion at 600°C also increased, as NaOH itself has a significant residue due to its impurities. DSC results showed the melting point of the samples and the amount of heat required to break the bonds. The heat of fusion for cellulose powder was 383.75 J/g, while the cellulose hydrogel had a much lower heat of fusion due to its amorphous structure. Those properties have advantageous for hydrogel application as wound dressing. The swelling capacity is essential to absorb wound exudates and maintain the moisture around the wound, while mechanical and elastic properties serve to protect the wound from the external impact and the high thermal stability aid in the sustained application of the hydrogel as wound dressing. Additionally, the cellulose based hydrogel exhibited good biocompatibility and possessed antibacterial activity against the growth of S.aureus and P.aeruginosa commonly found in wounds. The inhibition of those bacteria contributes to an accelerated wound healing process.

6. **LIST OF RESEARCH OUTPUT : - Submit to journal "Carbohydrate Polymers"**

Research Report
Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Title

Carbon sequestration and tree community's dynamics during 10 years of permanent plot monitoring at Mount Rinjani.

Principal Investigator:
Prof. Endah Sulistyawati

Academic Unit

Research Division	:	Forestry Technology
Faculty/School	:	School of Life Sciences & Technology

INSTITUT TEKNOLOGI BANDUNG

November 2023

I. IDENTITY PAGE

1. Title : Carbon sequestration and tree community's dynamics during 10 years of permanent plot monitoring at Mount Rinjani
2. Topic : Global environmental problems
3. Research Period : November 2022-November 2023
4. Principal Investigator :

Full Name : Endah Sulistyawati
Academic Rank : Professor
NIP : 196911191995122001
Current Position : Lecturer
Academic Unit : School of Life Sciences & Technology
Office Address/Phone/Fax/E-mail : Labtek XI, Jl. Ganesa 10 Bandung/ endah@itb.ac.id
Home Address/Phone/Fax/E-mail : Jl. Tanjungsari Asri Barat IV No 1 Bandung/08122041599

4.2 Members of the Team:

No	Name and Academic Rank	Field of Expertise	Institution	Allocation of Time	
				Hrs/week	Months
1	Dr. Nuri N. Setiawan	Ecology	Hungarian Research Institute of Organic Agriculture	5	10
2	Dr. Noviana Budianti	Ecology	SITH	5	10

4.3 Research Assistants/Students (mention names when available):

No	Name	Departement and NIM	Allocation of Time	
			Hrs/week	Months
1.	Gerald Yudha Putra	10618028	5	3
2.	Mirza Irsyad Rahman	10620040	5	6
3.	Raden Roro Chavita Bilqis Alentatia	10619075	5	2

5. Approved budget : IDR 90,384,000.

Dean of SITH

Prof. Endah Sulistyawati, SSi., PhD

Bandung, 30 November 2023
Principal Investigator

Prof. Endah Sulistyawati, SSi., PhD

I. EXECUTIVE SUMMARY

1. **TITLE OF RESEARCH** : Carbon sequestration and tree community's dynamics during 10 years of permanent plot monitoring at Mount Rinjani
2. **HEAD OF RESEARCH TEAM** : Prof. Endah Sulistyawati, SSi., PhD.
3. **TEAM MEMBERS** : Dr. Noviana Budianti, Dr. Nuri Nurlaila Setiawan,
4. **OFFICIAL ADDRESS** : Jl. Ganesa 10 Bandung

5. **EXTENDED ABSTRACT** :

A permanent plot monitored over a long-term period is a powerful tool for studying multiple tree species regeneration and growth. Such data can then be used for species selection designed to accelerate biodiversity recovery. A permanent plot can also provide information on the relationship between climate and forest dynamics when established in undisturbed areas. In 2013, a one hectare permanent plot was established in a natural forest of Mount Rinjani National Park, Lombok Island, West Nusa Tenggara Province. The plot is located in the montane vegetation area zone (2000 masl and the trees were firstly censused and reported by Muhammad (2014) and Sulistyawati et al. (2014). This study aims to remeasure the one-hectare permanent plot in Mount Rinjani ten years since the first measurement in 2013 with specific objectives to study: (1) Changes in tree community structure & composition, (2) The general tree community demographical pattern, and (3) The forest's ability on carbon sequestration. What unexpected was part of the study area was burnt before the 2023 survey. Therefore, the findings of this study reflect the dynamics of vegetation as affected by fire disturbance.

The result shows that fire affected 84% of the study plot, with almost 50% of the plot completely burnt. No changes in the species, but sharp decrease in the density due to fire that further reduced the basal area and diversity index in 2023. Fire greatly affected the forest stand (84% area) resulting in high mortality (death of 213 ind) mostly in the smallest diameter class (10-20 cm) with implication in reducing total basal area & diversity index in 2013-2023. Fire affected trees in all wood density classes. Decrease in the carbon stock means that fire has caused the forest stand acts as carbon source during 2013-2023. Species-specific demographic profile based on the surviving trees are to be analysed.

LIST OF RESEARCH OUTPUT : Draft manuscript consisting interim results to be used for composing 1 article in international journal (Q2) on the demographic pattern topic and 1 article in national journal (DIKTI-accredited) on carbon sequestration topic.

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Grant FY 2022/2023

Final Report

Development of Organic Rankine Cycle (ORC) with low GWP Refrigerant Based on pure Wood Pellet as Energy Source

1. Dr. Muhamad Yulianto
Department of Mechanical dan Biosystem Enginering, IPB University
2. Dr Edy Hartulistiyoso
Department of Mechanical dan Biosystem Enginering, IPB University
3. Dr. Leopold O. Nelwan
Department of Mechanical dan Biosystem Enginering, IPB University
4. Hendry, MT
Doctoral Sturdent Department of Mechanical dan Biosystem Enginering, IPB University
5. Assoc. Prof. Niccolo Giannetti
Department of Mechanical Applied, Waseda University
6. Prof. Kiyoshi Saito
Department of Mechanical Applied, Waseda University
7. Prof. Dede Hermawan
Department of Forest Product, IPB University

IPB University
Bogor Indonesia

Submitted to:

Environmental Research Center

IPB University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

November 2023

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)
Research Grant for 2022/2023: Progress Report

Date: Bogor, November 30th , 2023

I. Applicant Information

Name of project leader (Last name, first name)	Yulianto, Muhamad	Date of birth (Month, date, year)	07,10,1983
Institution	IPB University	Position	Lecturer (Project Leader)
Address of institution	Fakultas Teknologi Pertanian (FATETA) Institut Pertanian Bogor. Kampus IPB Darmaga, Jl. Raya Dramaga Kampus IPB Dramaga Bogor-West Java		
	Post code:16680	Tel. (+62251)86232026	Fax. (+62251)86232026
	E-mail: *tmb@apps.ipb.ac.id*	URL: https://tmb.ipb.ac.id/id/	
Home address	Pakuan Regency cluster lingga Buana Block A No. 21 Margajaya, Bogor Ctiy-west java		
	Post code: 16116	Tel: -	Fax. -
	E-mail: muhamad_yulianto@apps.ipb.ac.id	Mobile number:+6285866224992	
Name of contact person (*if other than project leader*)			
Contact Address (*if other than home or organization address*)			
	Post code:	Tel.	Fax.
	E-mail:	URL:	

II. Project Arrangement

Project team *Please include the project leader. If the team members are more than 5 persons, you can add extra pages*

Name	Age	Institution	Major	Role in the project
1) Dr. Muhamad Yulianto	38	Department of Mechanical and Biosystem Engineering, IPB University	Mechanical Engineering (Energy Conversion)	Project leader (Analysis for energy result for ORC system)
2) Dr. Edy Hartulistiyoso	59	Department of Mechanical and Biosystem Engineering, IPB University	Renewable Energy	Project team (Analysist for calory value of raw material and pellet)
3) Dr. Leopold O Nelwan	52	Department of Mechanical and Biosystem Engineering, IPB University	Renewable Energy	Project team (Analysist heat pump drying)
4) Hendri, MT	39	Department of Mechanical and Biosystem	Mechanical Engineering (Energy Conversion)	Project team (Data Collection)

		Engineering, IPB University (Doctoral Student)		
5) Assoc. Prof. Niccolo Giannetti	34	Waseda Institute for Advanced Study	Mechanical Engineering (Energy Conversion)	Project team (Simulation based on EFM)
6) Prof. Kiyoshi Saito	54	Department of Applied Mechanics and Aerospace Engineering, Waseda University	Mechanical Engineering (Energy Conversion)	Project team (Simulation based on EFM)
7) Prof. Dede Hermawan	59	Department of Forestry Product, IPB University	Bio composite	Project team (Wood Properties)

III. Project Setting

Theme: Renewable energy to strengthen community life and sustainable environment	
Topics: *For appropriate answer, please insert ✓in the box on the right*	
a. Access to modern energy services	
b. Energy efficiency improvement	
c. New technology and innovation in renewable energy	✓
d. Sustainability of renewable energy to enhance household economy	
e. Gender equality issues in the management of renewable energy sources	
f. Renewable energy and sustainable environment	

1. Title of the project
   Development of Organic Rankine Cycle (ORC) with Low GWP refrigerant based on Pure wood pellet As Energy Source

2. Summary of the project
   Please explain within 600 words: why the project is necessary, objectives, location, targeted beneficiaries, and results obtained so far.

   All over the world including Indonesia have program zero emission in 2050. The most of power plant in Indonesia using coal as energy source. Because of that program and condition, Ministry of Energy and Mineral have **plan to terminate 53 GW coal-fired power between 2025-2045.** Development of Organic Rankine Cycle (ORC) as an alternative system for generating electricity to achieve "zero emission" has long been introduced. ORC requires lower energy consumption than conventional Steam Power Plant (SPP) therefore its operation is possible using biomass. **This project is important because have potency when Indonesia terminate 53GW of coal-fired, this project will be applied as a substitute**. There are two problems in the development of ORC which are still being carried out, about working fluids and their energy sources. The problem of working fluid is for an environmentally friendly working fluid (Low GWP/ Global Warming Potential). Meanwhile, the problem of energy sources is focused on the use of sustainable biomass production with low energy consumption**. In this proposal the solution offered is to use a Low GWP refrigerant for the working fluid and lower energy for pellet production**. The pellets are from ***Gamal, Kaliandra and Sengon*** wood. The research method is based on simulation and experimental. **The objective of this research is providing a shorter method of making pellets will be made, using direct sawdust, dryer, pelletizer and then directly used in ORC where the previous method used generally consisted of chipper machine, coarse hammer mill, dryer, fine hammer mill, pelletizer and into the power generation process**.

   All of experiment and data collection will be implemented at Renewable Energy Division, Department of Mechanical and Biosystem Engineering IPB University

   In principle the **general beneficiaries of this research project are the world society who want clean energy especially Indonesian government who have target zero emission in 2050**.

3. Background and objectives of the project

Please give a concise description of problems and issues will be addressed that lead to the objectives of the project and why they are necessary to be solved.

The condition of electricity shortage problem in Indonesia is considered to have been completed because currently the electricity ratio in Indonesia has reached 99% as shown in Figure 1. **The problem is most of these power plants use fossil fuels (coal) around 63.9%** as can be seen in Figure 2. this is very problematic to achieve the target of zero emission in 2050

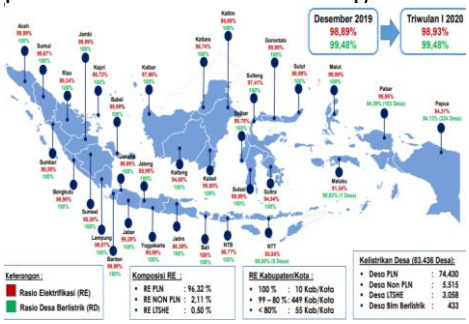


Figure 1. Electricity ratio in Indonesia

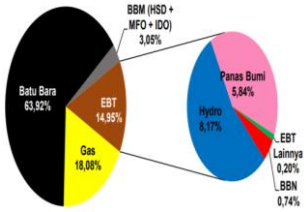


Figure 2. Energy source in power plant

On the other hand, nowadays many researchers reveal that ORC has the potential as a method of generating electricity that supports emission reduction towards zero emission. Generally, the cycle between ORC and Conventional steam power plant is same consist of pump, boiler, turbine and condenser, the differences only on the working fluid and energy consumption. In ORC using refrigerant as the working fluid, and the energy source have potential using pure pellet biomass. The problem is how to provide the working fluid with low GWP and how to produce pellet biomass with low energy. Normally, the production of wood pellet using 5 step machining, consist of: Chipper, Coarse hammer mill, dryer, fine hammer mill and pelletizer as can be seen in figure 3. Due to the length of this process, pelleting requires a lot of energy.

Figure 3. Pelletizer Process to be use in power plant

Therefore, in this research proposal have objective to reduce the process in pelletizer process by only use Wood sawdust, pelletizer, and dryer as can be seen in figure 4. In the other hand the working fluid of ORC using low GWP refrigerant. By this innovation the energy consumption in pellet production will be reduced until 40%. The material that will be used in pelletizer are ***Gamal, Kaliandra and Sengon*** wood

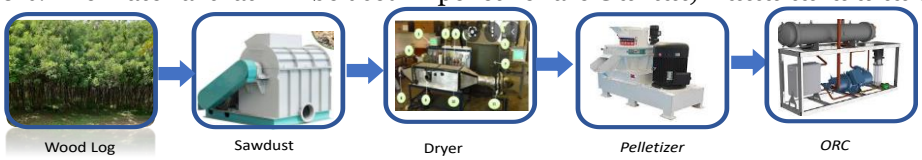


Figure 4. Innovation Pelletizer Process to be use in ORC

The facilities in our lab already have heat pump dryer (Ministry of higher education grant on 2017), ORC (ministry of higher education grant on 2018) and a pelletizer machine consisting of a chipper, sawdust and pellet machine (electricity company grant on 2020) as shown in Figure 5. In this study, we will modify all that machine.

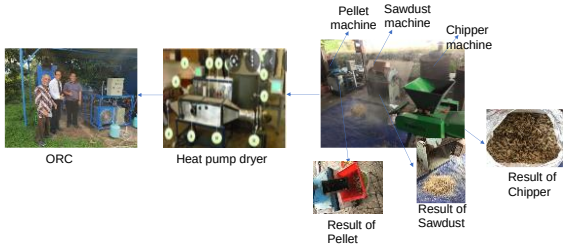


Figure 4. Facility for pellet machine and ORC

4. Target area(s) and beneficiaries *Why they are selected? Please provide detailed information on the area(s) and beneficiaries and enclose map(s) on separate sheet(s), if necessary.*

In principle the **general beneficiaries of this research project are the world society who want clean energy especially Indonesian government who have target zero emission on 2050**. Because of to create clean energy need to synergy from several sector such as energy source production, electricity generation and society as can be seen in figure 5, in research have target area in energy source production and electricity generation side. From **energy source production side** should produce energy source (biomass pellet) **with lowest energy consume**, in this project provide shorter the process of pellet production which is consists of: sawdust machine, dyer machine and pelletizer. From **electricity generation side**, in this project provide **Organic Rankine Cycle (ORC) Steam power plant method** with working fluid from Low GWP refrigerant. This innovation will produce clean electricity and environment friendly that can be used by world society specially Indonesia.

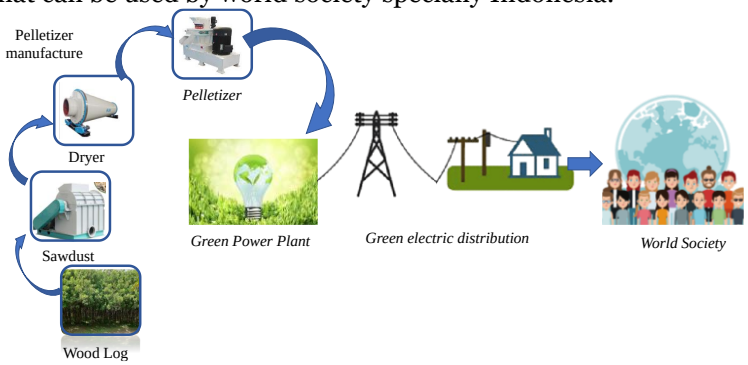


Figure 5. Scheme of target area and beneficiaries of this project

5. Methodology *Please explain in detail: what method, what will be investigated, and where. Please add separate sheet(s), including for map(s), formula(s), table(s), chart(s), etc., if necessary.*

material (gamal, kaliandra, sengon wood) will check the calorie value. After that the material will go to sawdust process, in this process will **investigate some parameter** such as: energy consumption, size of sawdust and capacity. The next process is drying (heat pump drying), in this step the **parameter will investigate** such as: energy consumption, drying time, moisture content and capacity. Next to the drying process the material will be palletization, and **the parameter will be investigated** such as energy consumption, moisture content, Calorie value and capacity. **This project will be guide into experiment and simulation in ORC for sawdust and pellet material. The parameter that will be investigate such as**: **Fuel consumption, energy consumption, efficiency, thermal characterization, and output power**.

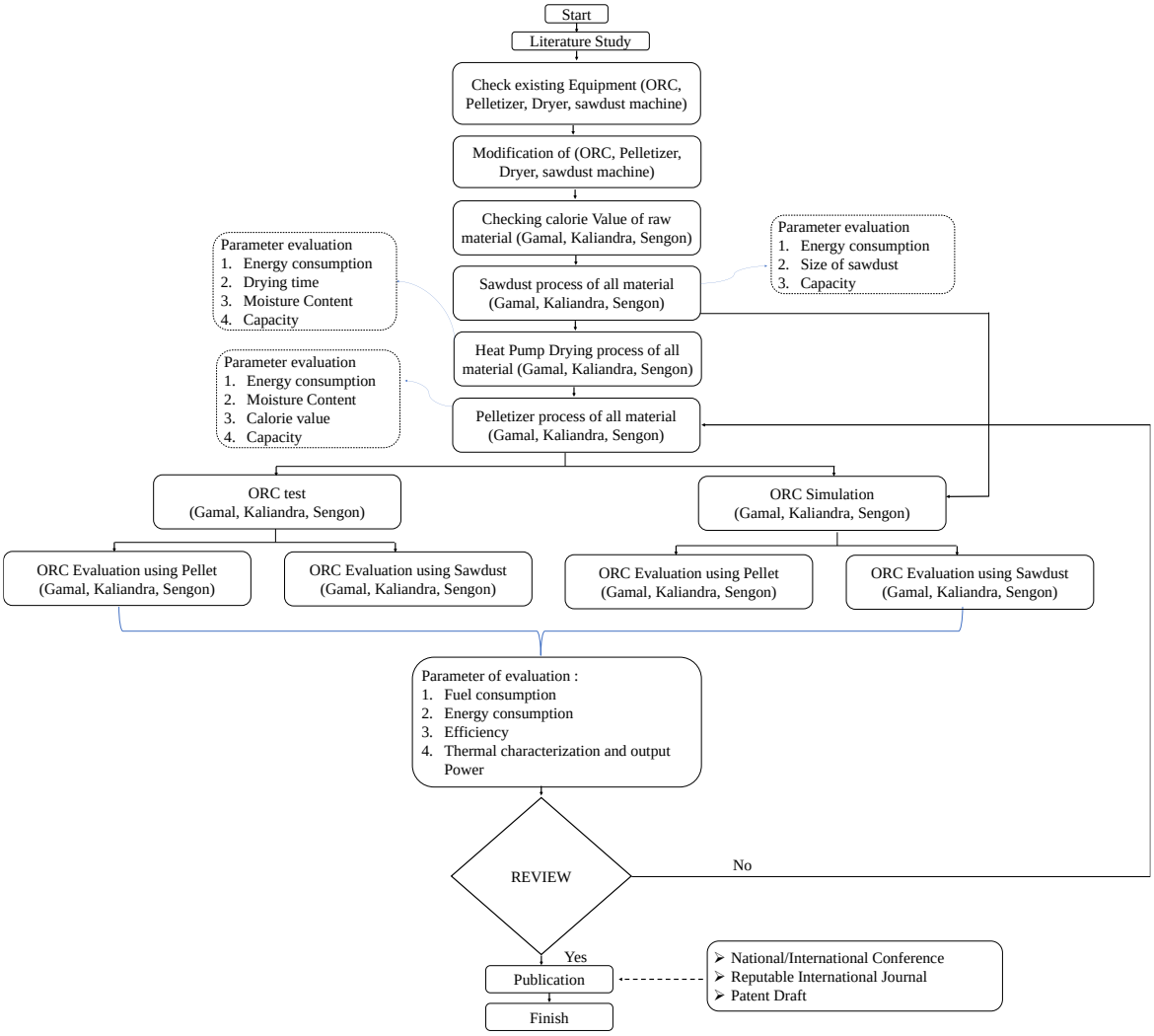
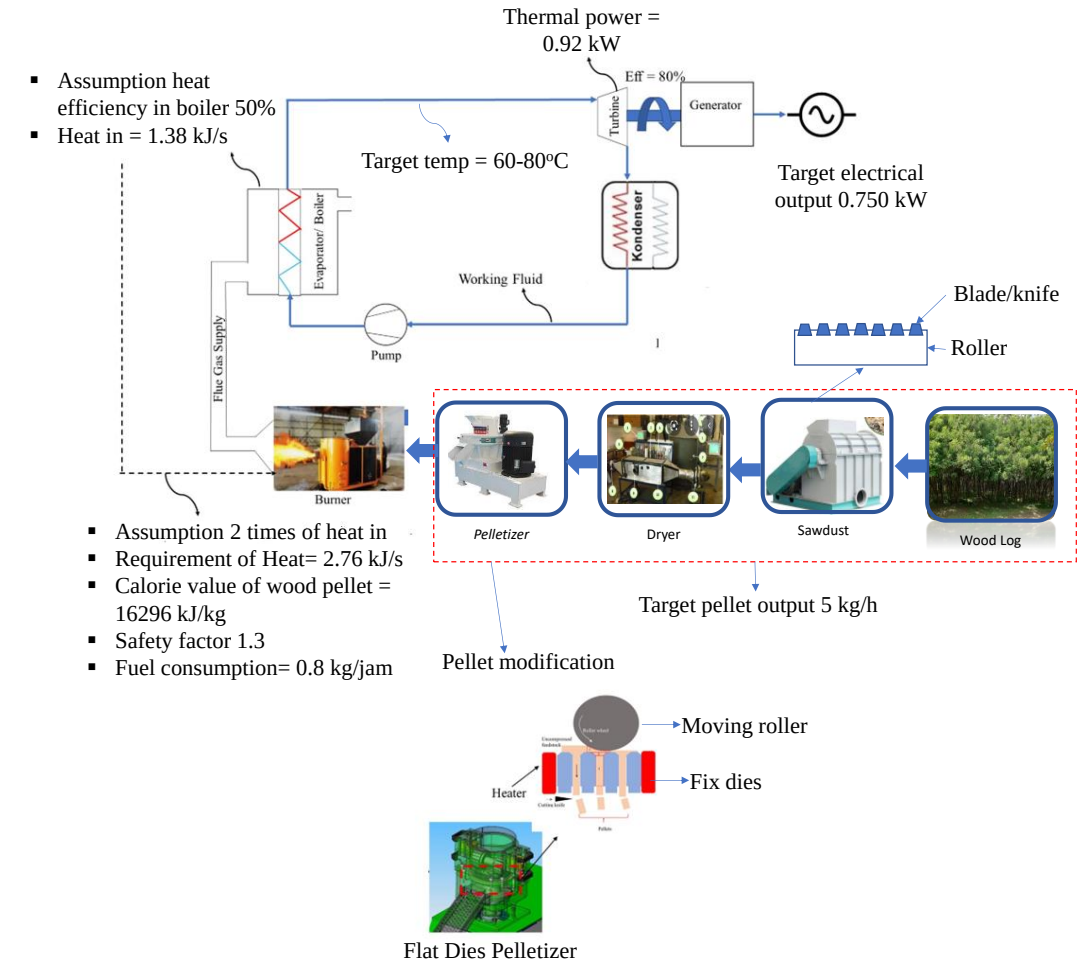


Figure 6. Schematic diagram of the project

Experiment set up can be seen in figure 7. In this project, the capacity of wood pellet production is 5 kg/hours and output power from ORC is around 0.75 kW. Based on the rough calculation, the thermal power around 0.92 in turbine with target temperature and pressure in ORC cycle around 60-700c and 15 – 20 bar. The heat input to boiler requires around 1.38 kJ/s. based on that condition, the fuel consumption in the burner will need around 0.8 kg/hour

All of experiment and data collection will be implemented at Renewable Energy Division, Department of Mechanical and Biosystem Engineering IPB University



- Assumption heat efficiency in boiler 50%
- Heat in = 1.38 kJ/s
- Assumption 2 times of heat in
- Requirement of Heat= 2.76 kJ/s
- Calorie value of wood pellet = 16296 kJ/kg
- Safety factor 1.3
- Fuel consumption= 0.8 kg/jam

Figure 7. Experiment set-up of the project

6. Result(s) obtained so far and the effect to target area(s) or the impact to beneficiaries *Please add separate sheet(s), including for map(s), formula(s), table(s), chart(s), etc., if necessary.*

a. Modification of saw dust machine.

As mentioned in the proposal, this research is conducted to reduce energy consumption in making pellets, especially in sawdust production. The modification of sawdust machine to reduce energy consumption as shown in fig 8. The sawdust machine is using hardening steel to plug into the cylinder as shown in figure 9.

Fig. 8. Sawdust Machine

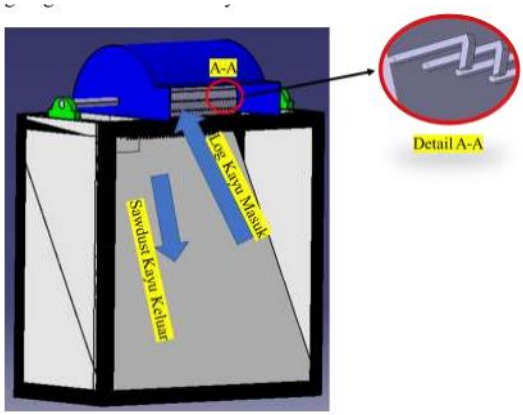


Fig 9. Design sawdust machine

This modification was tried to gamal and kaliandra wood by 6 experiments as shown on table 1 and 2. The experiment set up shown on Fig 10.

Table 1. Experiment sawdust from Gamal wood

No	Mass of Sawdust (kg)	Operation time (s)	Feed rate (kg/s)	Capacity (kg/h)	Energy (Watt)	Energy Specific (kW/kg)	Initial Moisture content (%)	Final Moisture Content (%)
1	1,30	72,00	0,02	65,00	2091,17	0,03	44,8	35,7
2	1,20	35,00	0,03	123,43	1789,13	0,01	43,4	35,9
3	1,00	50,00	0,02	72,00	2016,94	0,03	44,8	36
4	0,90	75,00	0,01	43,20	1918,83	0,04	43,4	36,1
5	0,70	35,00	0,02	72,00	1831,96	0,03	43,7	35,5
6	0,40	35,00	0,01	41,14	1625,69	0,04	44,5	35,7
Ave	0,92	50,33	0,02	65,56	1878,95	0,03	44,1	35,8

Table 2. Experiment sawdust from Kaliandra Wood

No	Mass of Sawdust (kg)	Operation time (s)	Feed rate (kg/s)	Capacity (kg/h)	Energy (Watt)	Energy Specific (kW/kg)	Initial Moisture content (%)	Final Moisture Content (%)
1	0,39	35,00	0,011	40,11	1822,83	0,05	13,5	12,8
2	0,25	35,00	0,007	25,71	1866,96	0,07	13,4	12,6
3	0,20	35,00	0,006	20,57	1531,47	0,07	13,3	12,5
4	0,18	25,00	0,007	25,92	1296,26	0,05	13,5	12,4
5	0,16	25,00	0,006	23,04	1592,72	0,07	13,2	12,6
6	0,09	25,00	0,004	12,96	997,08	0,08	13,4	12,6
Ave	0,21	30,00	0,007	24,72	1517,89	0,06	13,38	12,58

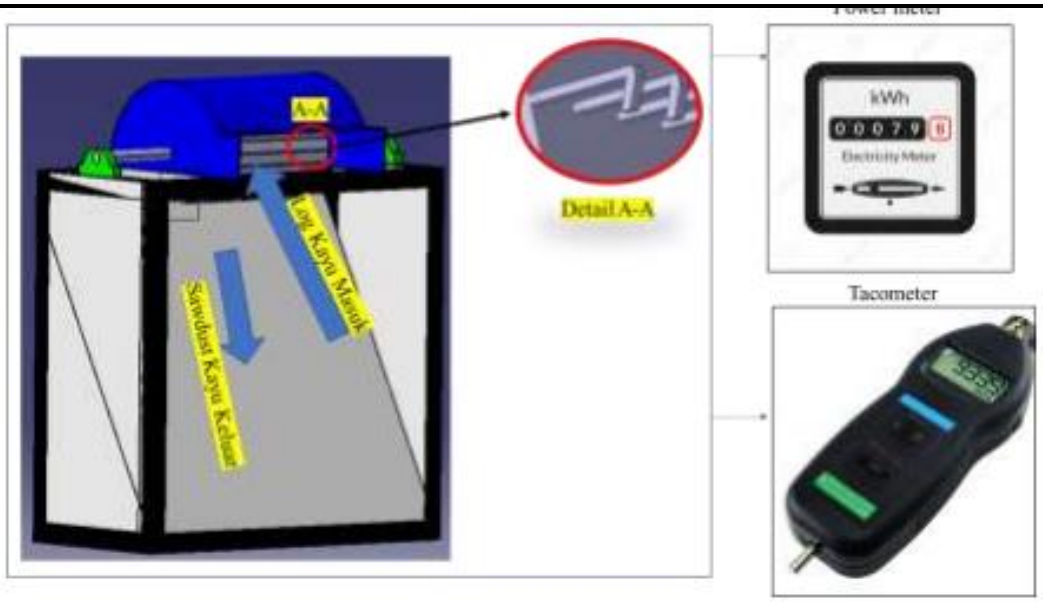
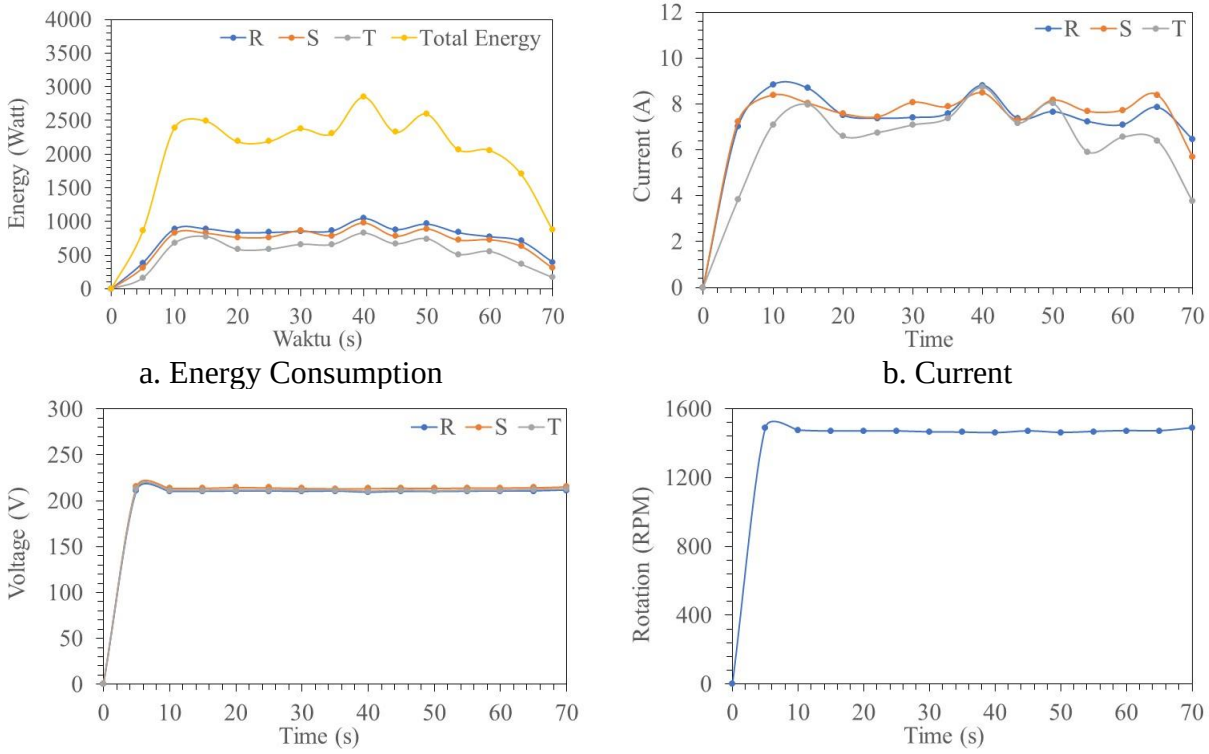


Fig 10. Exprimental set up

Power charactristics of gamal processing is shown on Fig 11-16. The feedrate is no constant because of the feeding rate was conducted my manually. Its have effect to the power consumption, current and rotation of machine. If the feeding rate is push to high condition, the power and current will be increase but the rotation will be decreased. Voltage was relative stable in this processing.



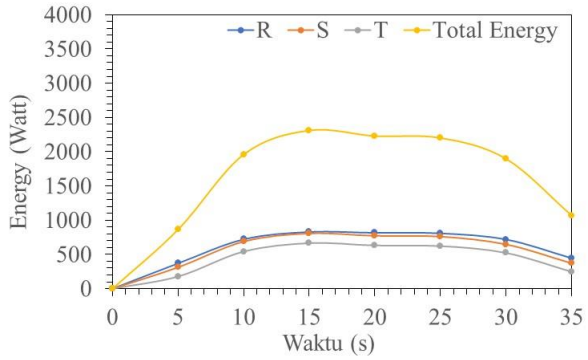
a. Energy Consumption

b. Current

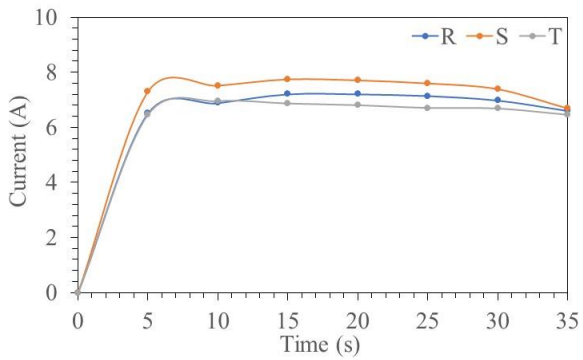
c. Voltage

d. Rotation

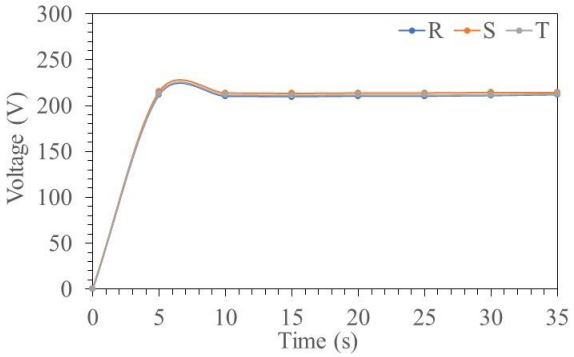
Figure 11. Process of 1,3 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



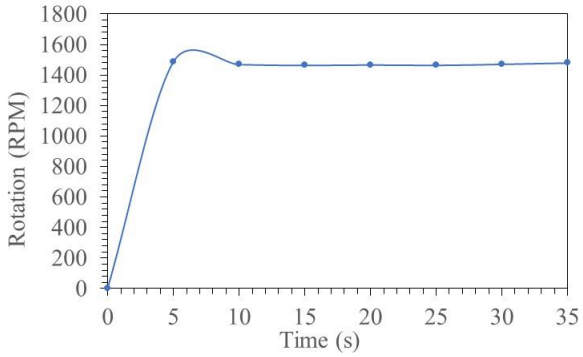
a. Energy Consumption



b. Current

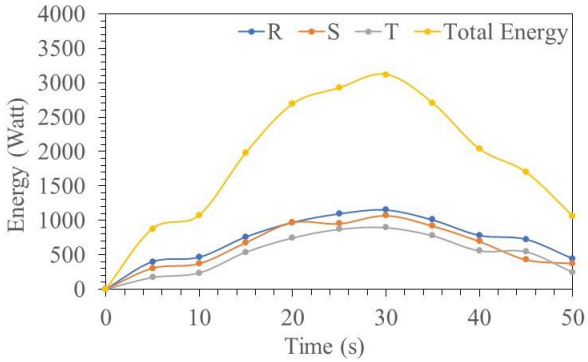


c. Voltage

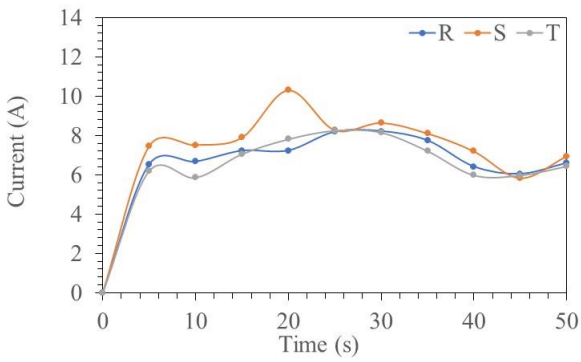


d. Rotation

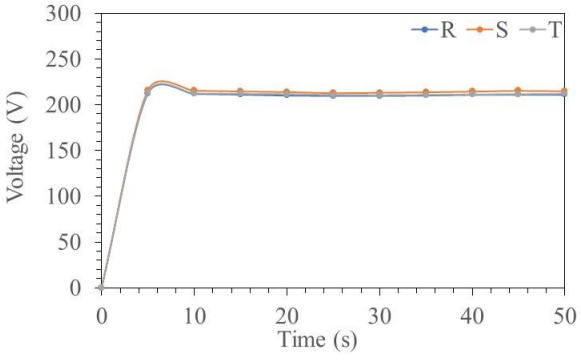
Figure 12. Process of 1,2 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



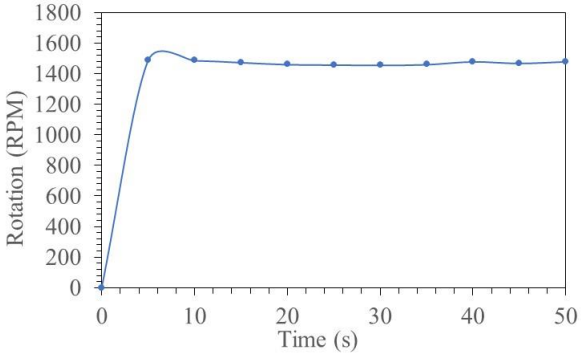
a. Energy Consumption



b. Current

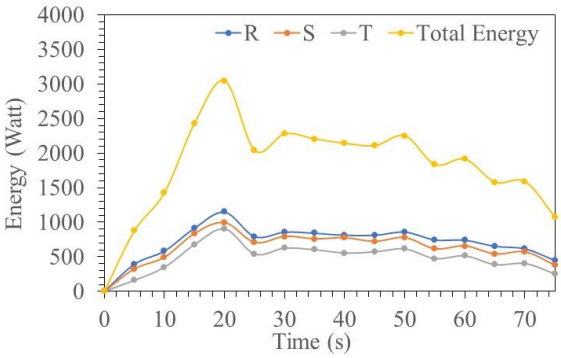


c. Voltage

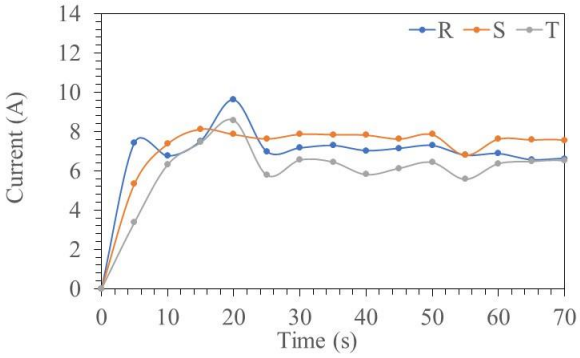


d. Rotation

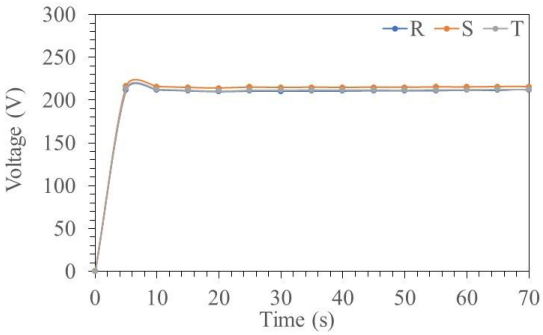
Figure 13. Process of 1 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



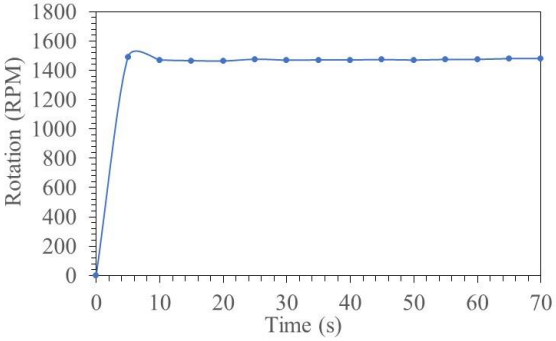
a. Energy Consumption



b. Current

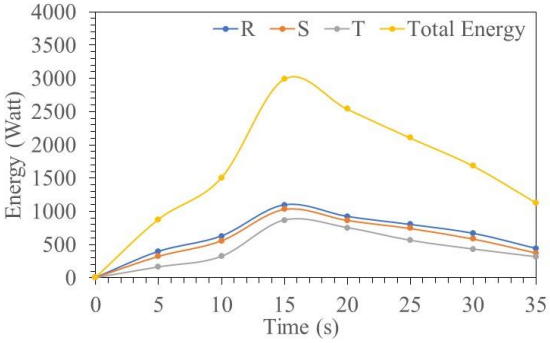


c. Voltage

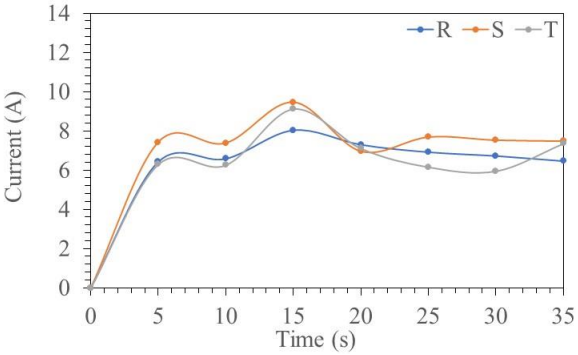


d. Rotation

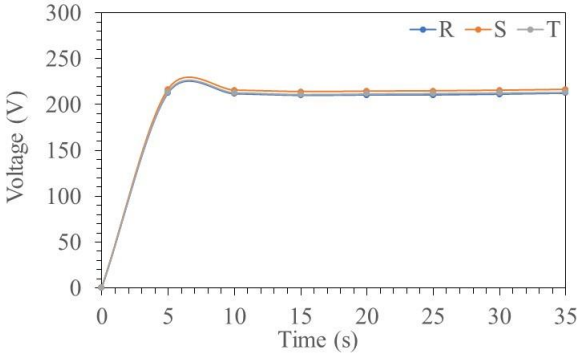
Figure 14. Process of 0,9 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



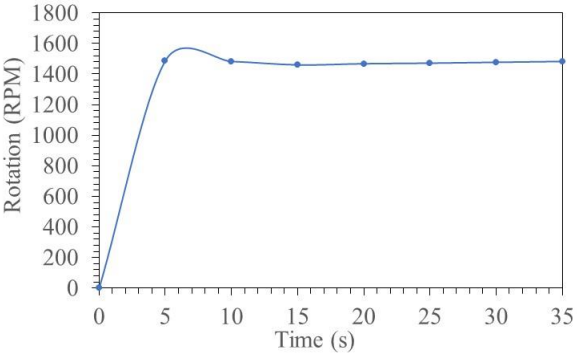
a. Energy Consumption



b. Current

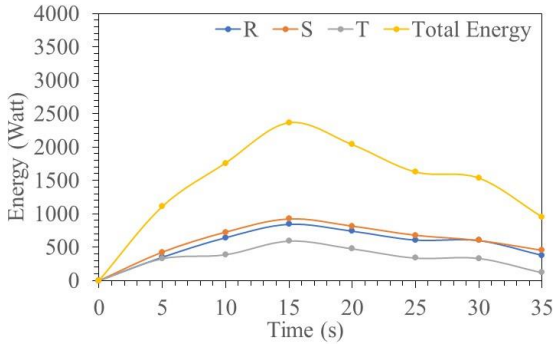


c. Voltage

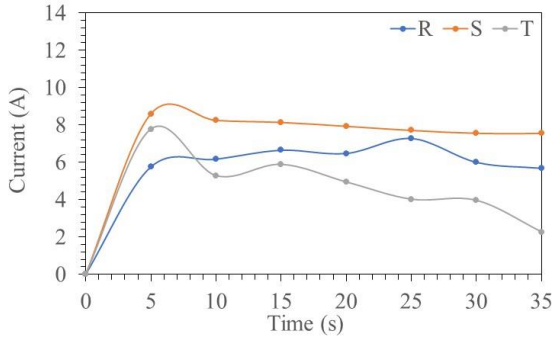


d. Rotation

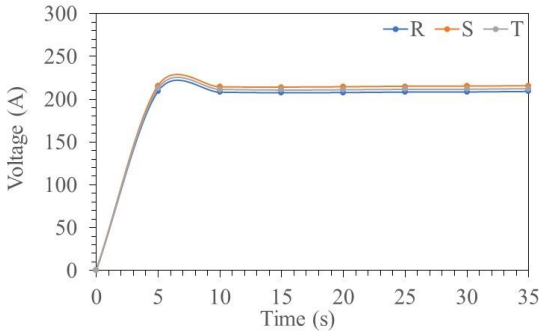
Figure 15. Process of 0,7 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



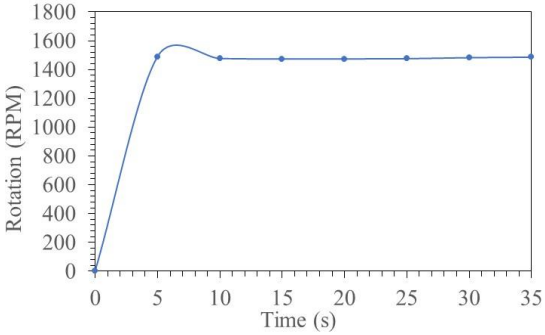
a. Energy Consumption



b. Current



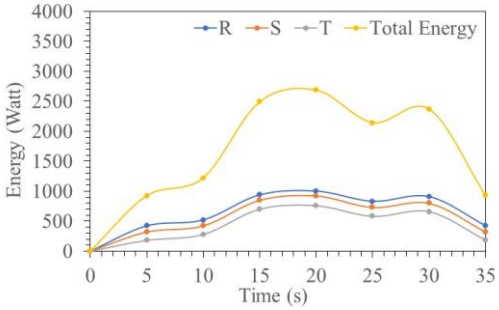
c. Voltage



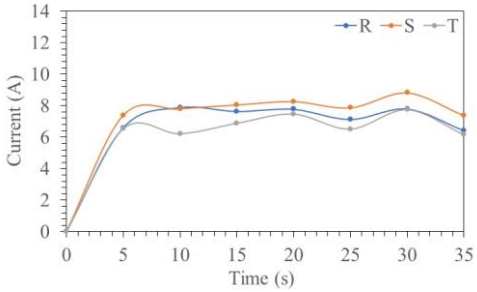
d. Rotation

Figure 16. Process of 0,4 kg of Gamal wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

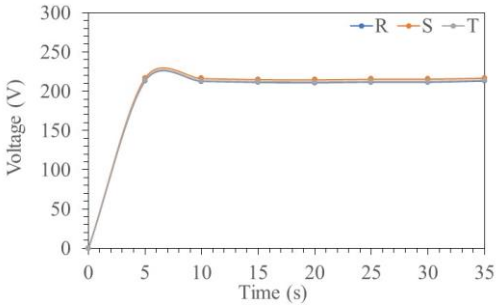
The characteristic of energy consumption and performance sawdust machine for Kaliandra wood can be seen in figure 17-22. The energy consumption characteristics of making sawdust from calliandra are not much different compared to gamal where if the feeding pressure is large, the power and current will increase but the rotation will decrease



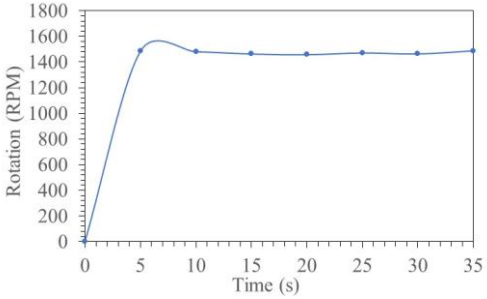
a. Energy Consumption



b. Current

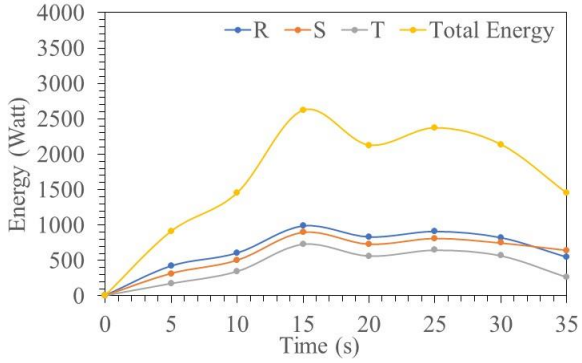


c. Voltage

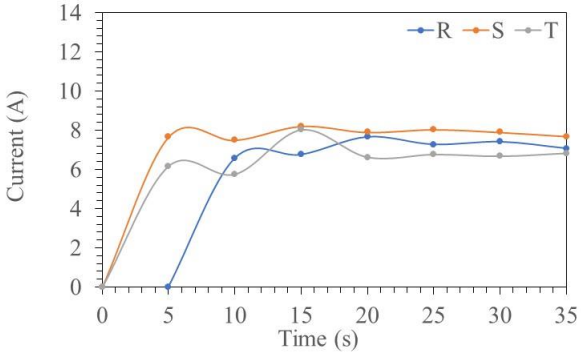


d. Rotation

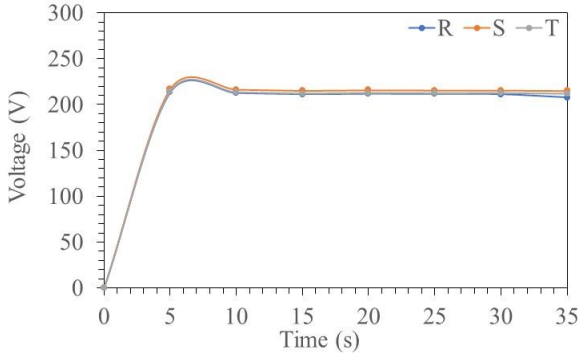
Figure 17. Process of 0,39 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



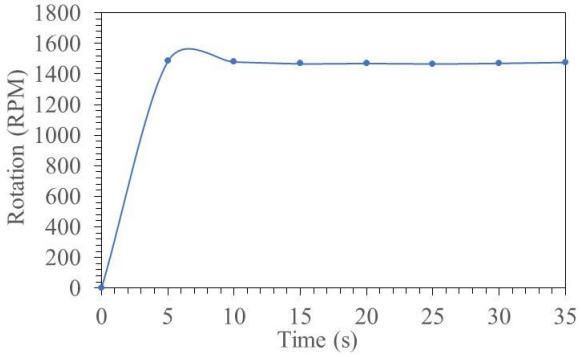
a. Energy Consumption



b. Current

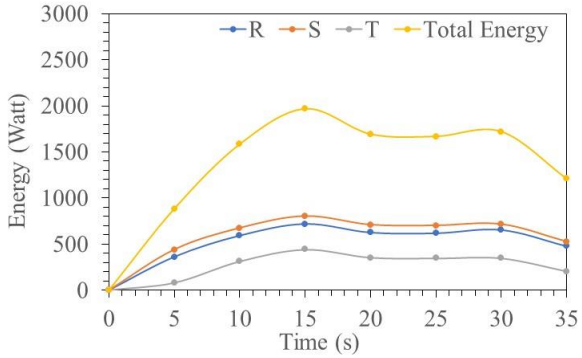


c. Voltage

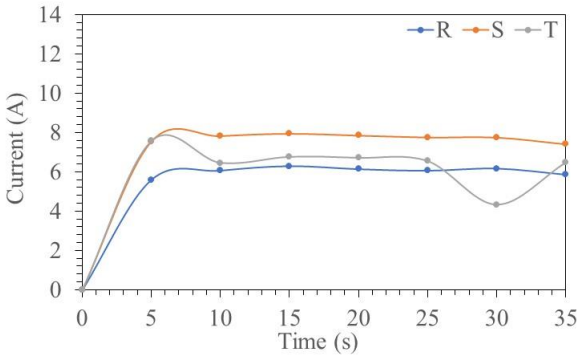


d. Rotation

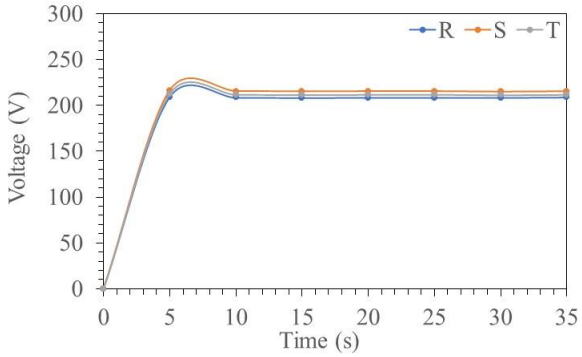
Figure 18. Process of 0,25 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



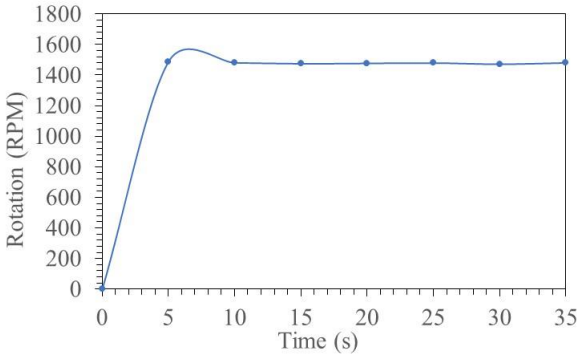
a. Energy Consumption



b. Current

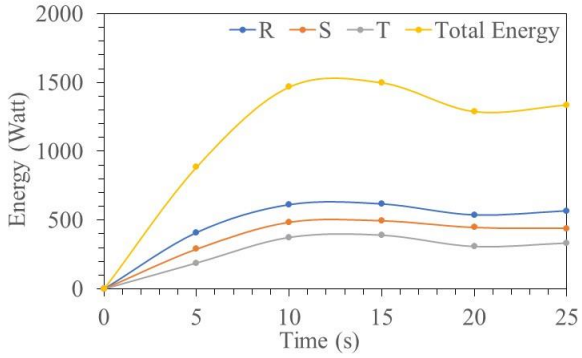


c. Voltage

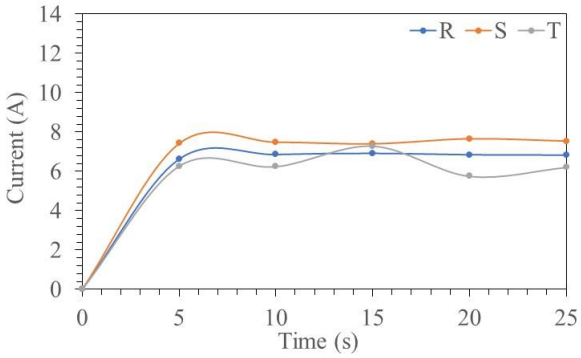


d. Rotation

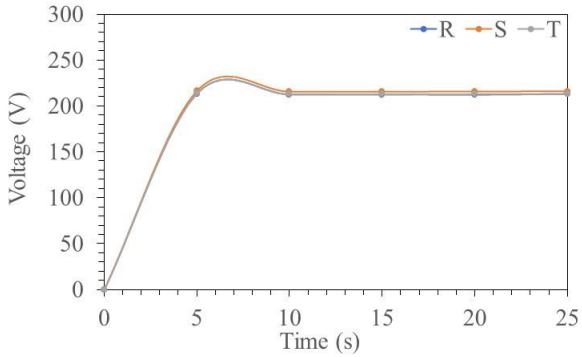
Figure 19. Process of 0,2 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



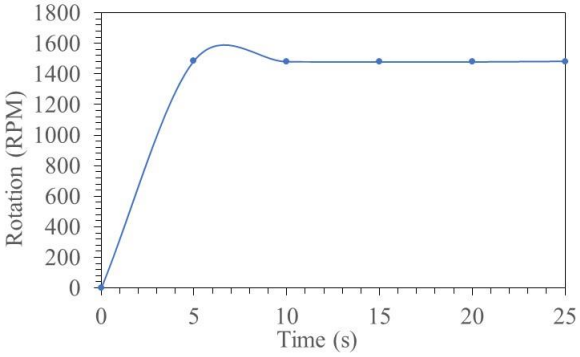
a. Energy Consumption



b. Current

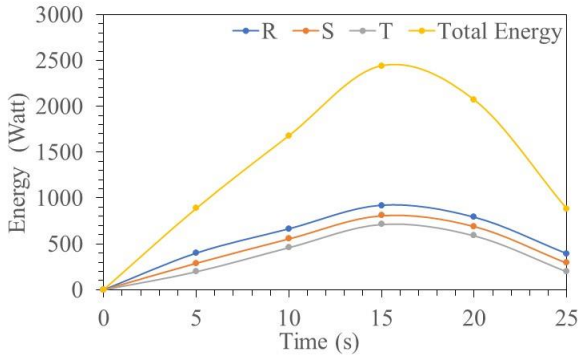


c. Voltage

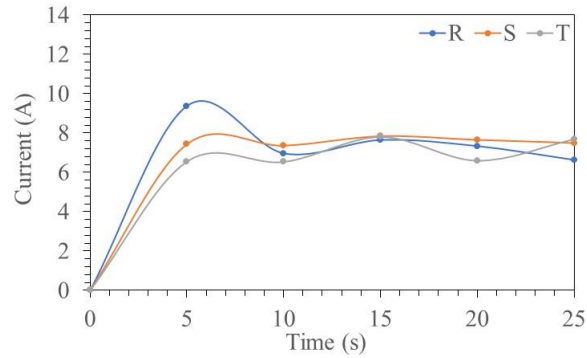


d. Rotation

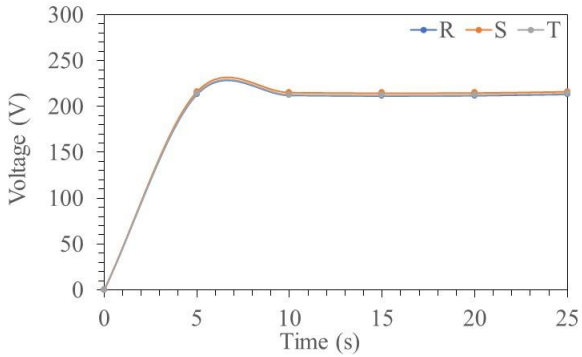
Figure 20. Process of 0,18 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



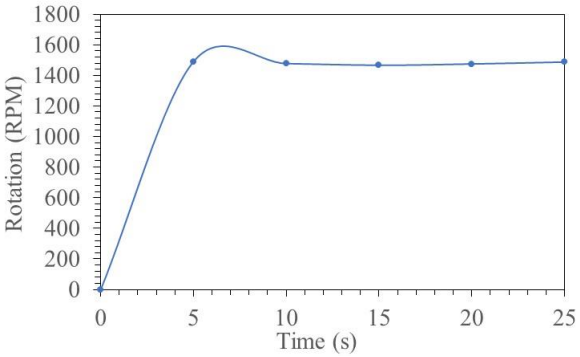
a. Energy Consumption



b. Current

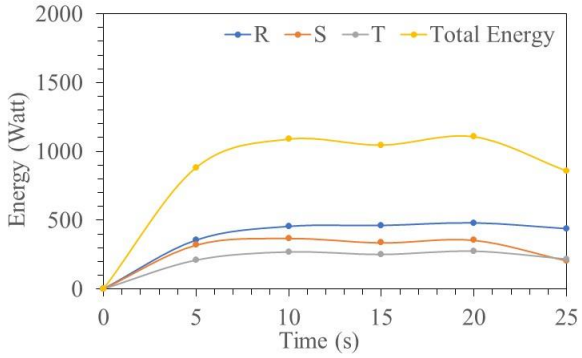


c. Voltage

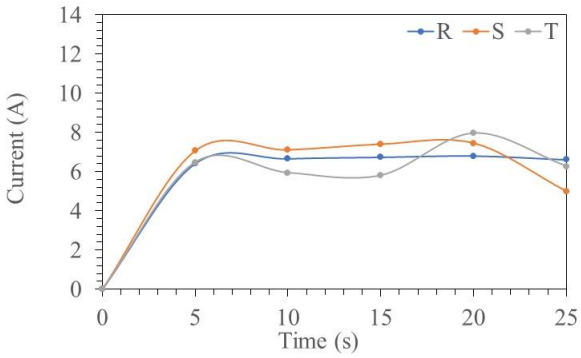


d. Rotation

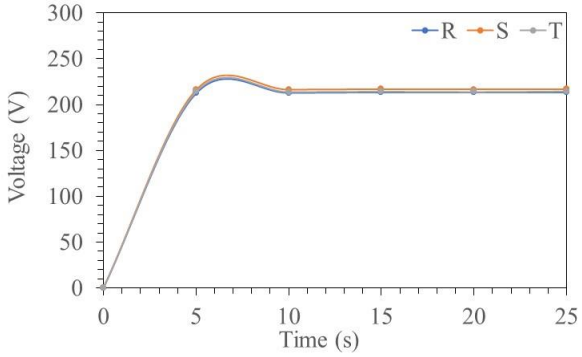
Figure 21. Process of 0,16 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation



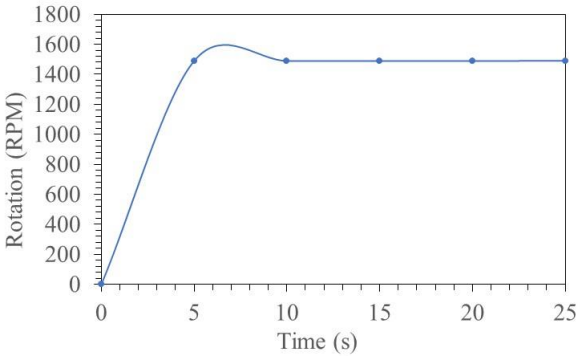
a. Energy Consumption



b. Current



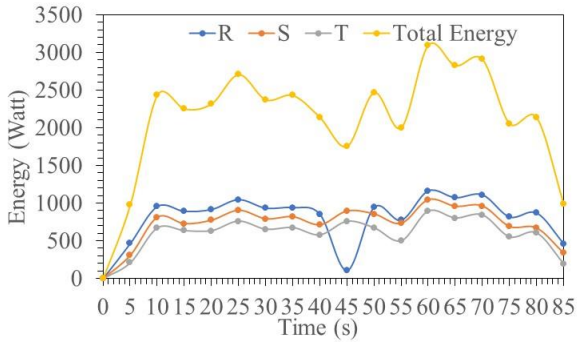
c. Voltage



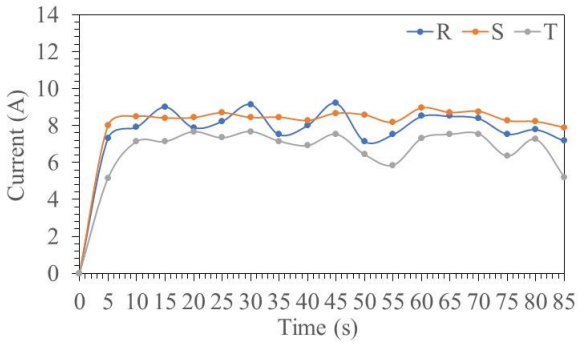
d. Rotation

Figure 22. Process of 0,09 kg of Kaliandra wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

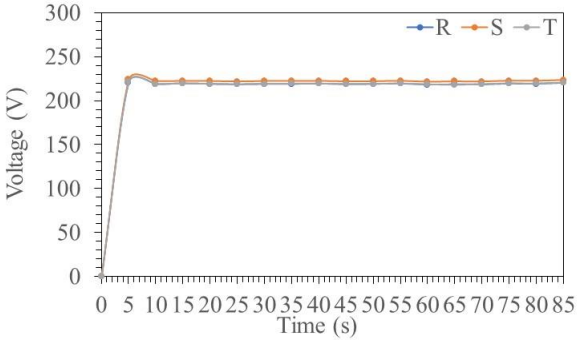
The characteristic of energy consumption and performance sawdust machine for Sengon wood can be seen in figure 23-28. The energy consumption characteristics of making sawdust from calliandra are not much different compared to gamal and calliandra where if the feeding rate is higher, the power and current will increase but the rotation will decrease



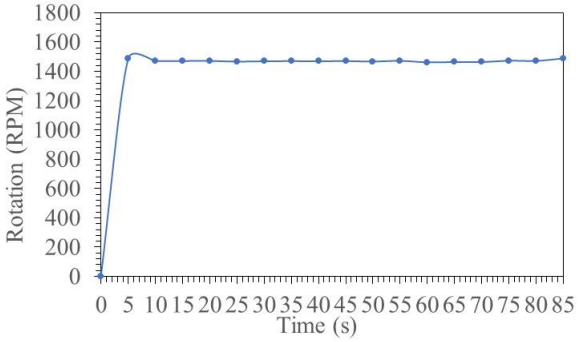
(a)



(b)



(c)



(d)

Figure 23. Process of 1,1 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

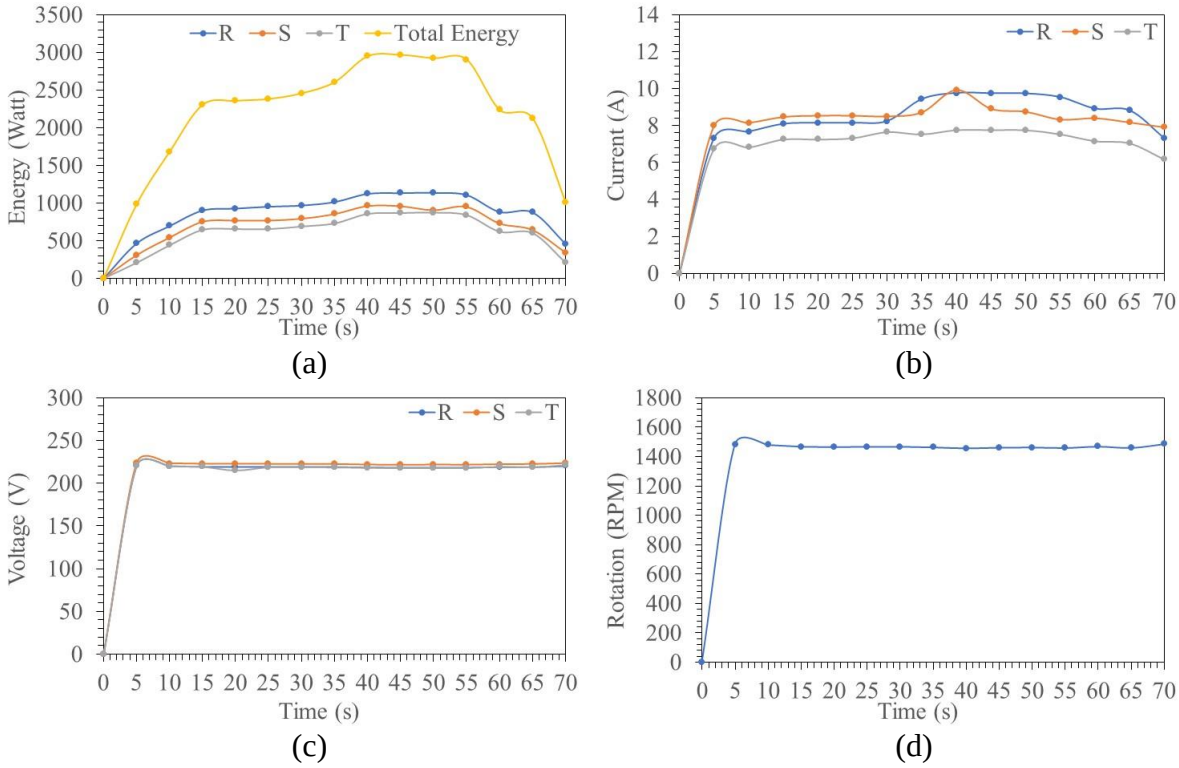


Figure 24. Process of 0,9 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

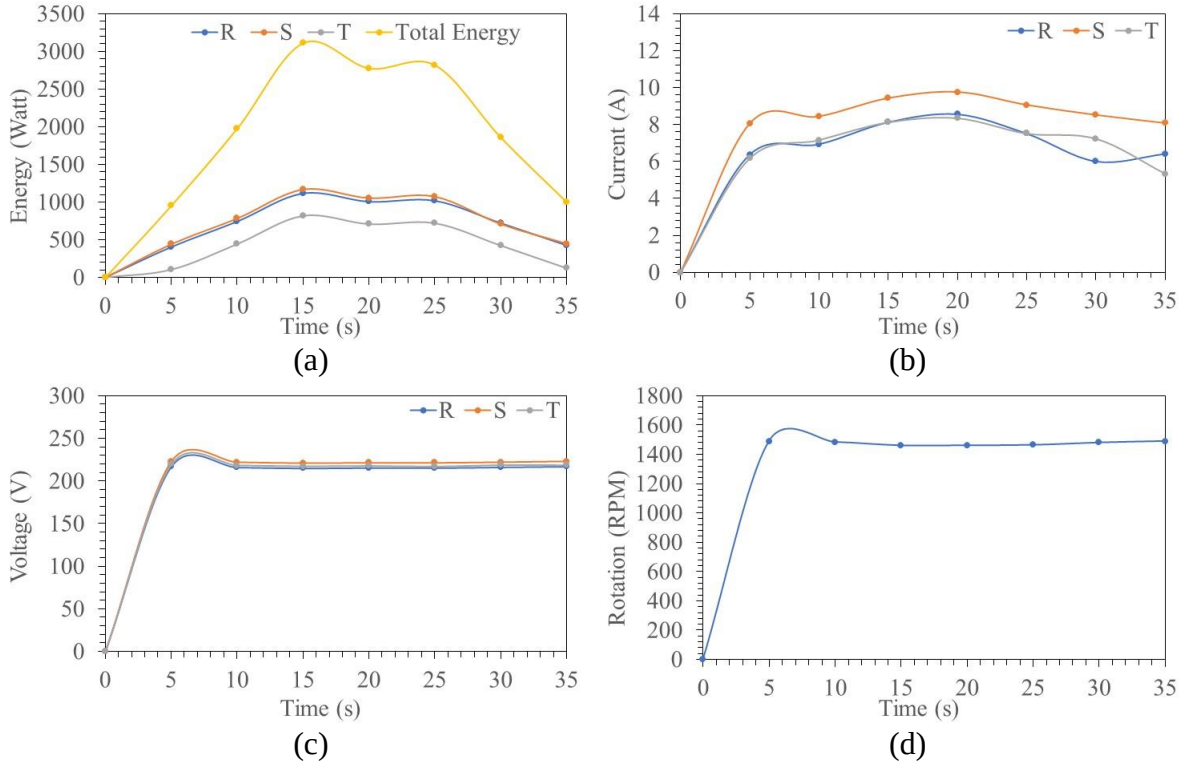


Figure 25. Process of 0,7 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

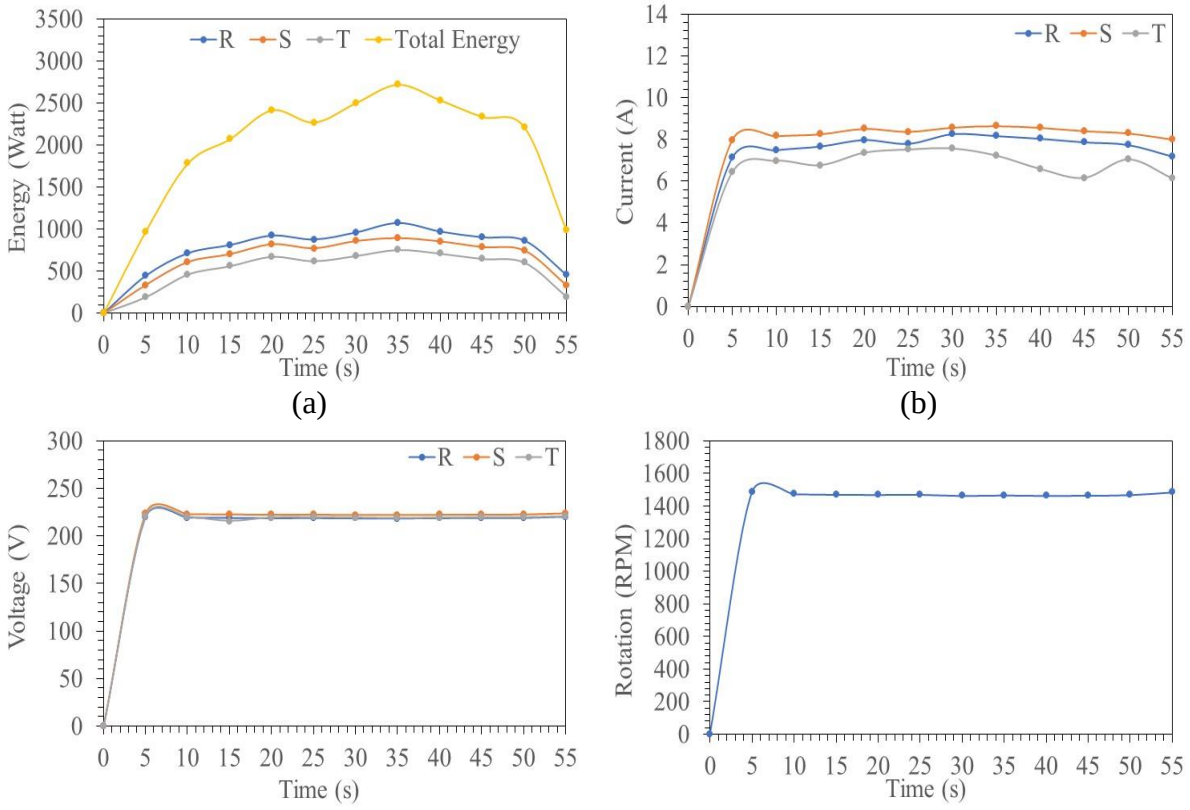


Figure 26. Process of 0,5 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

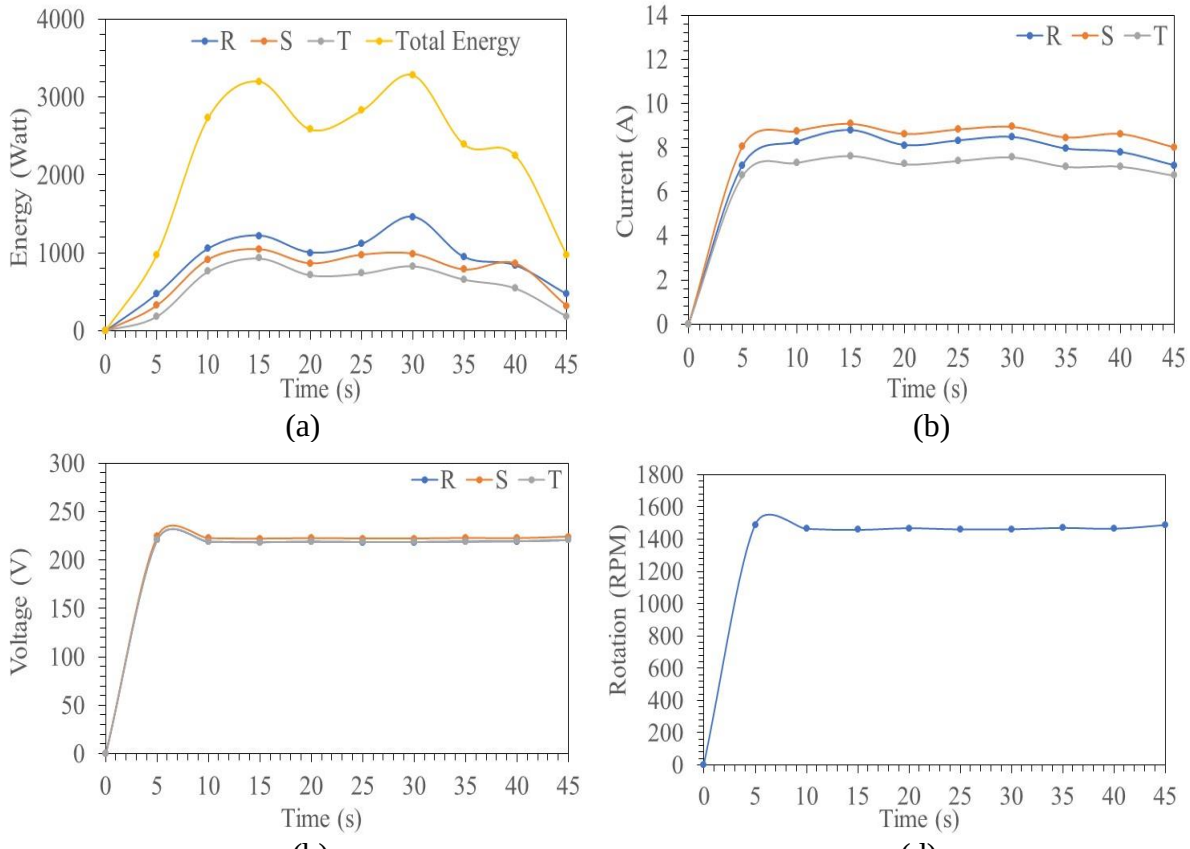


Figure 27. Process of 0,6 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

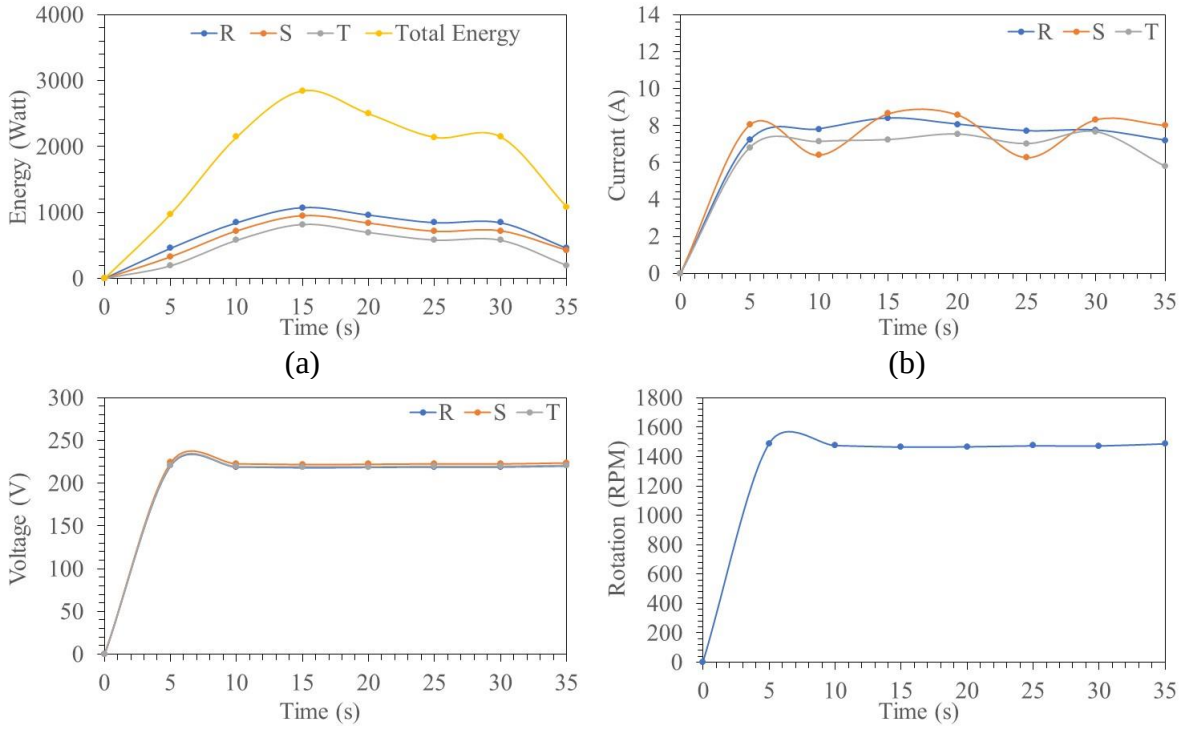


Figure 28. Process of 0,4 kg of Sengon Wood : a) Energy consumpton, b) Current, c)Voltage, d) Rotation

b. Drying process

In this research the drying process using heat pump compression method that develop by Nelwan et al with rated capacity are 5 kg of wood. The experiment set up of heat pump drying can be seen in figure 29.

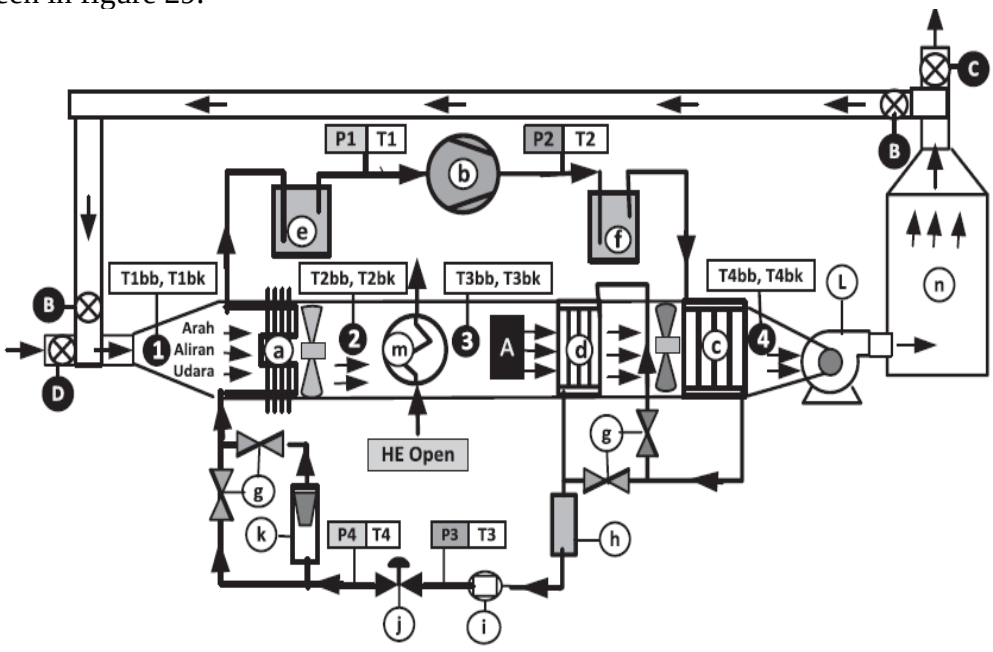


Fig. 29. Heat pump drying experiment set-up

In this experiment the air velocity is variate from 3.4, 4.2 and 5.8 m/s for each gamal and kaliandra wood. The energy specific of this process can be seen in table 3 for gamal and table 4 for Calliandra and table 5 for Sengon

Table 3. Energy specific for Gamal Wood in Drying Process

No	Air Velocity (m/s)	Initial Mass (kg)	Final Mass (kg)	Initial Moisture content (%)	Final Moisture Content (%)	Energy Consumtpion (Watt)	Energy Specific (kW/kg)
1	3,4	1	0,72	35,8	10,8	679,22	0,48
2	4,2	1	0,72	35,8	10,8	798,16	0,57
3	5,8	1	0,72	35,8	10,8	875,44	0,62

Table 4. Energy specific for kaliandra wood in drying process

No	Air Velocity (m/s)	Initial Mass (kg)	Final Mass (kg)	Initial Moisture content (%)	Final Moisture Content (%)	Energy Consumtpion (Watt)	Energy Specific (kW/kg)
1	3,4	1	0,72	12,58	9,38	807,85	4,04
2	4,2	1	0,72	12,58	9,38	782	3,91
3	5,8	1	0,72	12,58	9,38	726,28	5,68

Table 5. Energy specific for Sengon wood in drying process

No	Air Velocity (m/s)	Initial Mass (kg)	Final Mass (kg)	Initial Moisture content (%)	Final Moisture Content (%)	Energy Consumtpion (Watt)	Energy Specific (kW/kg)
1	3,4	1	0,6	53,2%	28,2	785,08	0,392
2	4,2	1	0,6	53,2%	28,2	775,90	0,387
3	5,8	1	0,6	53,2%	28,2	980,86	0,490

The product of sawdust result of the drying process can be seen in figure 24 and 25

a. Sawdust of Gamal b. Sawdust of Kaliandra

Fig. 30. Product result from drying process

c. Model Calculation

The calculation step is based on Eq.1 to Eq. . The First calculation step is calculating the amount of force to cut the wood log as shown in Eq 1. In the cutting force calculation (F_c), the parameter modulus rapture of wood (σ_g) and the Cutting area of knife (A) should be known. In Eq. 2 is the mass material (m) for each feeding and calculated by the density of the material (ρ) and volume of the material for each feeding (V). Eq. 3 Show the rotation of knife (N) that calculated from feed rate $(\dot{m})$, the mass for each feeding (m), amount of knife (n). The power required to cutting the wood shown in Eq. 4 (P_C) is calculated from cutting force (F_c) and cutting speed (v_c). Another parameter that calculates is the force due to the weight of cutting system (F_w) as can be seen in Eq. 5. Force due to weight of cutting system calculate from rotation of cutting system (ω), radius of cutting system $(R_0)$and mass of cutting system (m_c). The power requirement due to weight of cutting system (P_w) calculate from Force due to weight of cutting system (F_w), radius of cutting system (R_0), and the rotation of knife (n) as can be seen in Eq. 6. The total power requirement (P_{tot}), is calculate from Power due to Power of wood cutting (P_C) and weight of cutting system as can be seen in eq.7. The input parameter to calculate Eq.1- Eq.7 shown in table 6.

$$F_C = \sigma_g * A \quad (1)$$

$$m = \rho * V \quad (2)$$

$$N = \frac{\dot{m}/m}{n} \quad (3)$$

$$P_C = F_C * v_C \quad (4)$$

$$F_w = \omega^2 * R_0 * m_c \quad (5)$$

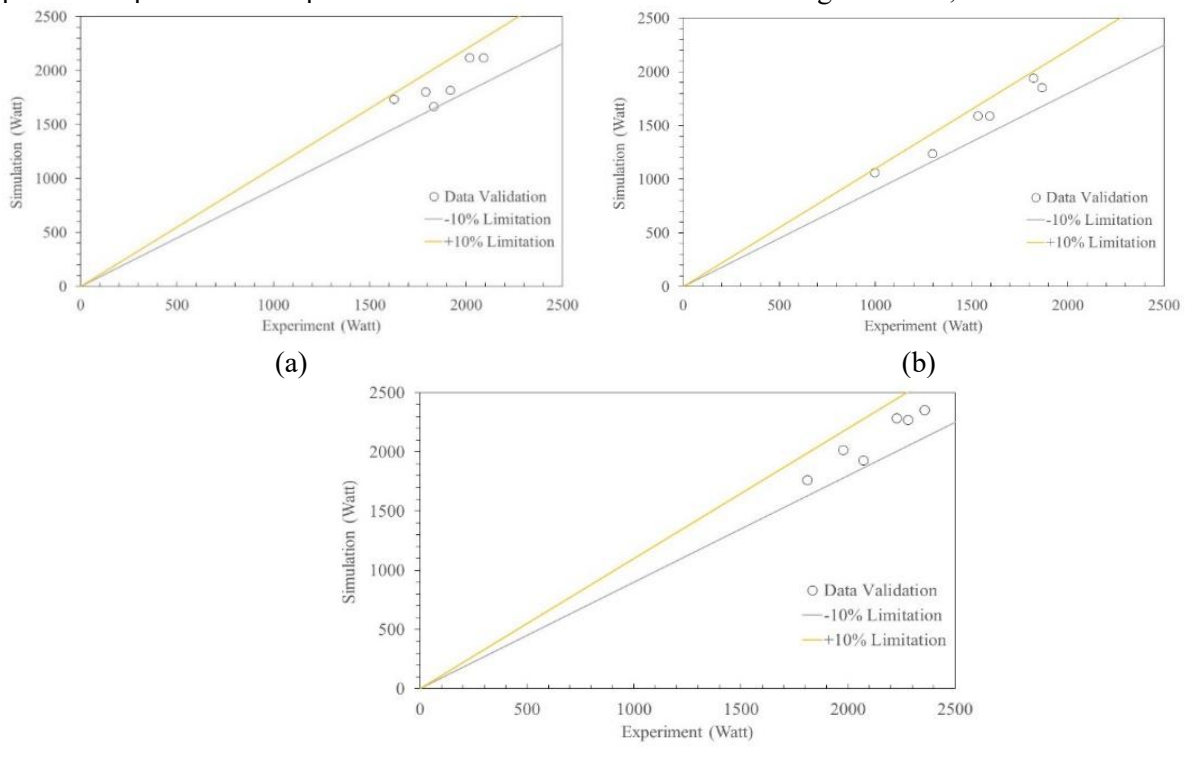
$$P_w = F_w * R_0 * N \quad (6)$$

$$P_{tot} = P_c * P_w \quad (7)$$

Table 6. Parameter input for calculation based on modification of wood sawdust machine

No	Parameter input	Value	Unit
1	Machine Rotation	Based on Experiment	RPM
2	Diameter of Shaft	20	mm
3	Diameter of Cutting cylinder	120	mm
4	Feeding rate	0,011	kg/s
5	Density of wood	650	kg/m3
6	Depth of feed	Based on Experiment	mm
7	Modulus Rapture of Wood	55,95	N/mm2
8	Diameter of Wood	0,05	m
9	Length between knife	10	mm
10	Mass Cutting System	30	kg
11	Safety Factor	1,3	

Fig. 31 show the validation result between experiment and simulation for each mass of Gamal (a), Calliandra (b), and Sengon wood (c). The error of validation shows less than 10% with the condition of wood properties such as Modulus of Rapture (MOR) and density using general wood. The cutting system dimension such as diameter (shaft and cutting roller), length between knife, mass of cutting system and safety factor based on the condition in table 2. If the validation error is less than 10%, it typically implies that the model's performance on a validation dataset is considered acceptable or good. Based on the error of validation, this model can be used to predict the power consumption of sawdust machine from the wood log of Gamal, Calliandra and Sengon wood.



(a) (b)

(c)

Fig. 31. Validation between experiment and simulation :(a) Gamal, (b) Calliandra, (c) Sengon

d. Calculated specific energy for sawdust process.

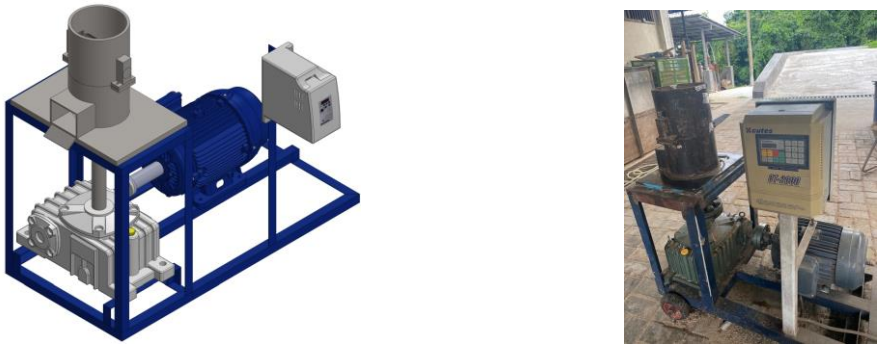
The target in this research is to reduce the energy consumption for sawdust process from previous one which is in sawdust process need 4 step that are: chipper, coarse hammer mill, drying, and fine hammer mill. Table 6 shows the comparison energy specific for the modification and previous process in the making of sawdust. From the calculation of this research, modification of sawdust machine can reduce energy specific about 62,5% from the previous process.

Table 6. Comparison of Energy specific for making sawdust

No	Man	Capacity (kg)	Power Consumption (kW)				Total Energy Consumption (kW)	Energy Specific (kW/kg)
			Chipper / Sawdust	Coarse Hammer Mill	Dryer	Fine Hammer Mill		
1	Man A	8000	103,4	326	151	326	906,4	0,113
2	Man B	8000	125	306	136,5	306	873,5	0,109
3	This Research							
	Gamal	69,46	1,878	NA	0,875	NA	2,754	0,042
	Calliandra	24,72	1,517	NA	0,807	NA	2,324	0,094
	Sengon	47,79	2,121	NA	0,915	NA	3,036	0,063

e. Pelletizing Process

The next activity in this research is the process of pelletizing Gamal Calliandra and Sengon wood. This activity begins with making technical drawings and replacing the die and rollers on the existing pellet machine as seen in Figure 32. This pellet machine uses a 1.5 HP motor that connects to 1/10 gear box. The die is made from steel with a diameter of 200mm and diameter of pellet 8 mm. The roller is connected to the dies with diameter 50mm and made from steel also. The height of roller is adjustable depending on the height of the material. The die and roller are also covered by steel.



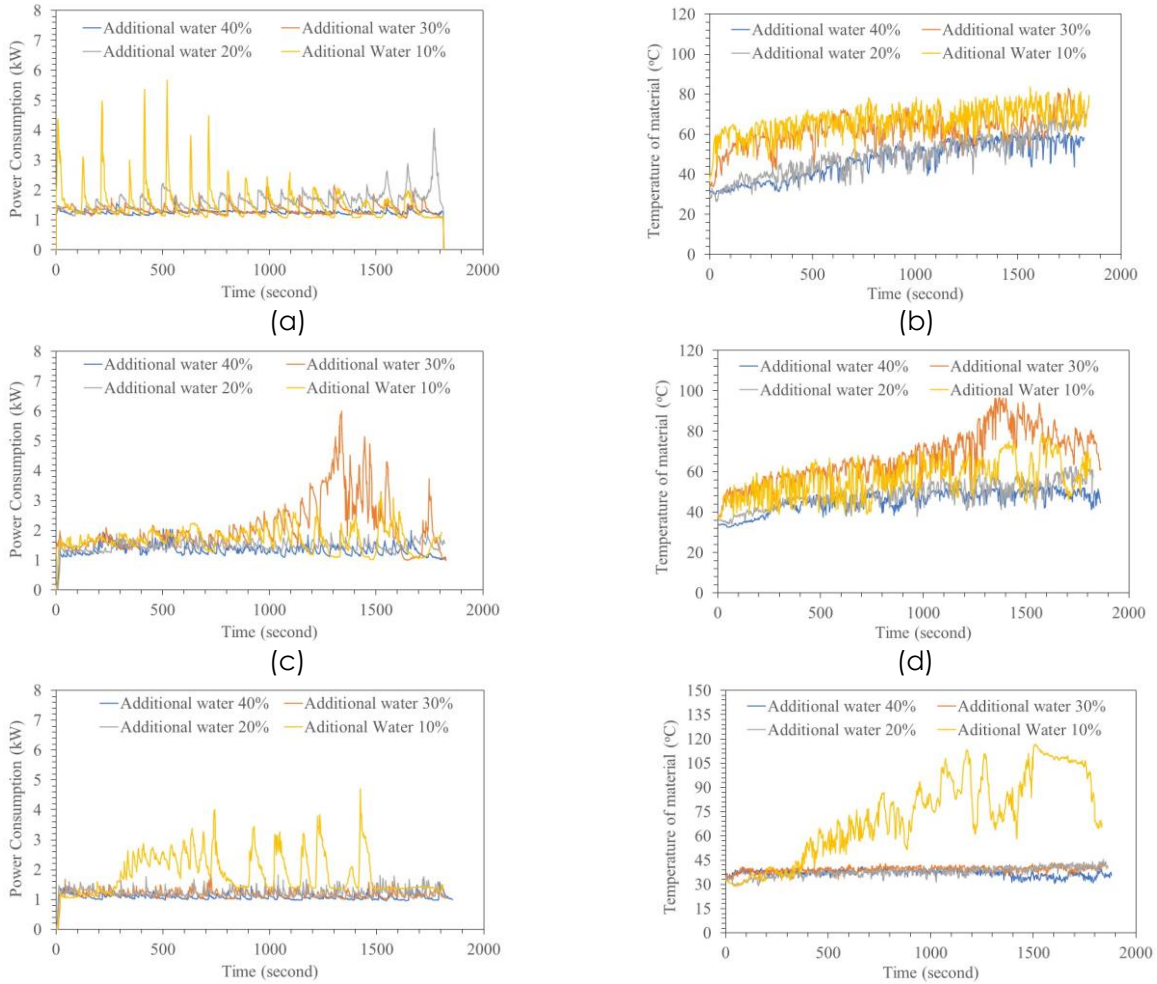
(a) (b)

Fig. 32. Pelletizer: (a) Design, (b) modification result

The experiment of pellet production for Sengon, Gamal, and Calliandra is based on the table 7 below. The condition is varied based on addition of water in the sawdust to clarify the effect of water content in the sawdust for pellet production.

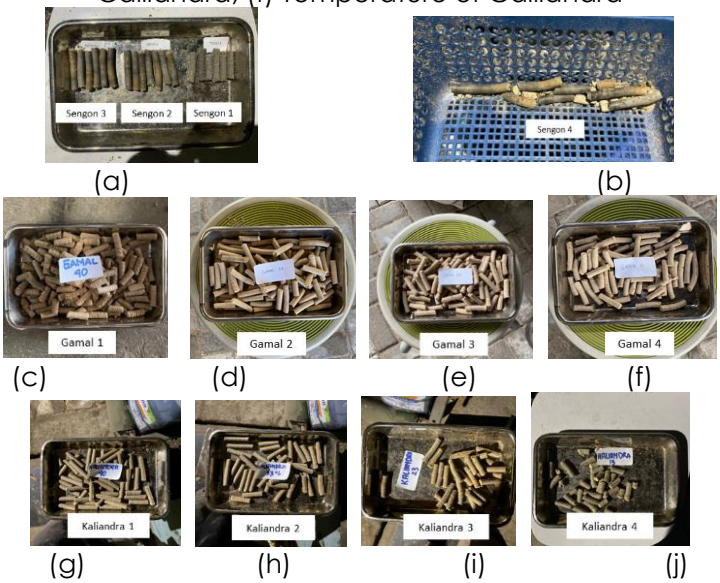
No	Material	Mass of material (kg)	Additional Water (%)	Operation Time (minutes)
1	Sengon 1	2,5	40	30
2	Sengon 2	1,5	30	30
3	Sengon 3	1,3	20	30
4	Sengon 4	1,15	10	30
5	Gamal 1	1,7	40	30
6	Gamal 2	1,5	30	30
7	Gamal 3	1,95	20	30
8	Gamal 4	1,15	10	30
9	Kaliandra 1	5,8	40	30
10	Kaliandra 2	5,2	30	30
11	Kaliandra 3	4,55	20	30
12	Kaliandra 4	1,15	10	30

Figure 33 (a)-(f) show the profile of power consumption and temperature for Sengon, Gamal and Calliandra. From that figure informs that the lowest additional water will have effect on the increasing on power consumption and temperature in the pelletizer process. When the temperature increases more than 80°C, the product will stick in the die and the process will be stopped. In the other side, id the process produces high temperature as mentioned before the productivity and quality of pelletizer machine also will be decreased as shown on figure 34 (a)-(j).



(e) (f)

Fig. 33. Profile of peletizer: (a) Power consumption of sengon, (b) Temperature of sengon, (c) Power consumption of Gamal, (d)Temperature of Gamal, (e) Power Consumption of Calliandra, (f) Temperature of Calliandra



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

Fig. 34. Product of pellet (a)Sengon 1-3, (b) sengon 4, (c) gamal 1, (d) gamal 2, (e) gamal 3, (f) gamal 4, (g) Calliandra 1, (h) Calliandra 2, (i) Calliandra 3, (j) Calliandra 4

f. Proximate and Ultima Result

The Proximate and ultimate result is shown in Figure 35 (a) – (c).

BADAN PENGEMBANGAN SUMBER DAYA MANUSIA ENERGI DAN SUMBER DAYA MINERAL

LABORATORIUM PENGUJIAN

BALAI PENDIDIKAN DAN PELATIHAN TAMBANG BAWAH TANAH

JALAN SOEKARNO HATTA DURIAN II, SAWAHLUNTO - SUMATERA BARAT

TELEPON : (0754) 61604 / HP:0811776655 website : bdbt.esdm.go.id e-mail : lab.bdbt@esdm.go.id

SERTIFIKAT ANALISIS

(Certificate of Analysis)

NO. RA/116/08/2023

Tanggal/ *Date*	:	30 Agustus 2023 *August 30th, 2023*
Dibuat untuk/ *Certified for*	:	Lalu Aziz Al-Azhari *Lalu Aziz Al-Azhari*
Alamat/ *Address*	:	Bogor *Bogor*
Jenis Sampel/ *Type of Sample*	:	Sawdust *Sawdust*
Kode Sampel/ *Code of Sample*	:	Sengon *Sengon*
Asal Sampel/ *Origin of Sample*	:	Bogor *Bogor*
Sifat dan Kondisi Sampel/ *Description of Sample*	:	≥4.75 mm, Kering, Dalam kemasan tidak kedap uap air *≥4.75 mm, Dry, In vapour not resistance container*
Tanggal Penerimaan Sampel/ *Date of Sample Receivation*	:	23 Agustus 2023 *August 23rd, 2023*
Tanggal Pelaksanaan Analisis/ *Date of Analysis*	:	28 Agustus 2023 sampai dengan 30 Agustus 2023 *August 28th, 2023 to August 30th, 2023*

HASIL ANALISIS / *ANALYSIS RESULTS:*

Parameter Uji/ *Testing Parameter*	AR	Adb	Satuan/ *Unit*	Standar Acuan / *Reference Standards*
*Total Moisture**	20.77	-	%	ASTM D3302-19
Ash Content	-	1.47	%	ASTM D3174-12
*Fixed Carbon**	-	16.54	%	ASTM D3172-13
Gross Calorific Value	-	4281	Kcal/Kg	Instrument (ASTM D 5865-19)
Sulfur Content	-	0.20	%	ASTM D 4239-18 combustion method A (1350°C)
*Carbon**	-	50.31	%	ASTM D5373-21
*Hitrogen**	-	5.04	%	ASTM D5373-21
*Nitrogen**	-	1.49	%	ASTM D5373-21

Keterangan / *Explanation:*
*Diluar lingkup akreditasi ISO/IEC 17025:2017 / *Out of scope ISO/IEC 17025:2017*
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NO. RA/115/08/2023

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Dibuat untuk/ *Certified for*	:	Lalu Aziz Al-Azhari *Lalu Aziz Al-Azhari*
Alamat/ *Address*	:	Bogor *Bogor*
Jenis Sampel/ *Type of Sample*	:	Sawdust *Sawdust*
Kode Sampel/ *Code of Sample*	:	Gamal *Gamal*
Asal Sampel/ *Origin of Sample*	:	Bogor *Bogor*
Sifat dan Kondisi Sampel/ *Description of Sample*	:	≥4.75 mm, Kering, Dalam kemasan tidak kedap uap air *≥4.75 mm, Dry, In vapour not resistance container*
Tanggal Penerimaan Sampel/ *Date of Sample Receivation*	:	23 Agustus 2023 *August 23rd, 2023*
Tanggal Pelaksanaan Analisis/ *Date of Analysis*	:	28 Agustus 2023 sampai dengan 30 Agustus 2023 *August 28th, 2023 to August 30th, 2023*

HASIL ANALISIS / *ANALYSIS RESULTS:*

Parameter Uji/ *Testing Parameter*	AR	Adb	Satuan/ *Unit*	Standar Acuan / *Reference Standards*
*Total Moisture**	12.54	-	%	ASTM D3302-19
Ash Content	-	2.88	%	ASTM D3174-12
*Fixed Carbon**	-	18.22	%	ASTM D3172-13
Gross Calorific Value	-	4274	Kcal/Kg	Instrument (ASTM D 5865-19)
Sulfur Content	-	0.26	%	ASTM D 4239-18 combustion method A (1350°C)
*Carbon**	-	48.84	%	ASTM D5373-21
*Hitrogen**	-	5.02	%	ASTM D5373-21
*Nitrogen**	-	1.49	%	ASTM D5373-21

Keterangan / *Explanation:*
*Diluar lingkup akreditasi ISO/IEC 17025:2017 / *Out of scope ISO/IEC 17025:2017*
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Alamat/ *Address*	:	Bogor *Bogor*
Jenis Sampel/ *Type of Sample*	:	Sawdust *Sawdust*
Kode Sampel/ *Code of Sample*	:	Kaliandra *Kaliandra*
Asal Sampel/ *Origin of Sample*	:	Bogor *Bogor*
Sifat dan Kondisi Sampel/ *Description of Sample*	:	≥4.75 mm, Kering, Dalam kemasan tidak kedap uap air *≥4.75 mm, Dry, In vapour not resistance container*
Tanggal Penerimaan Sampel/ *Date of Sample Receivation*	:	23 Agustus 2023 *August 23rd, 2023*
Tanggal Pelaksanaan Analisis/ *Date of Analysis*	:	28 Agustus 2023 sampai dengan 30 Agustus 2023 *August 28th, 2023 to August 30th, 2023*

HASIL ANALISIS / *ANALYSIS RESULTS:*

Parameter Uji/ *Testing Parameter*	AR	Adb	Satuan/ *Unit*	Standar Acuan / *Reference Standards*
*Total Moisture**	20.86	-	%	ASTM D3302-19
Ash Content	-	2.49	%	ASTM D3174-12
*Fixed Carbon**	-	18.38	%	ASTM D3172-13
Gross Calorific Value	-	4782	Kcal/Kg	Instrument (ASTM D 5865-19)
Sulfur Content	-	0.18	%	ASTM D 4239-18 combustion method A (1350°C)
*Carbon**	-	50.42	%	ASTM D5373-21
*Hitrogen**	-	5.02	%	ASTM D5373-21
*Nitrogen**	-	1.49	%	ASTM D5373-21

Keterangan / *Explanation:*
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(c)

Fig. 35. Proximate and ultimate result : (a) Sengon, (b) Gamal, (c) Calliandra

g. Modification of Biomass Organic Rankine Cycle
Modification of Organic Rankine Cycle can be seen in figure 36. The ORC system consists of Biomass stove, Pump, Boiler, Expander and Vapor compression cooling.

Fig 36. ORC Biomass

The test result of ORC can be seen ini Fig 26.

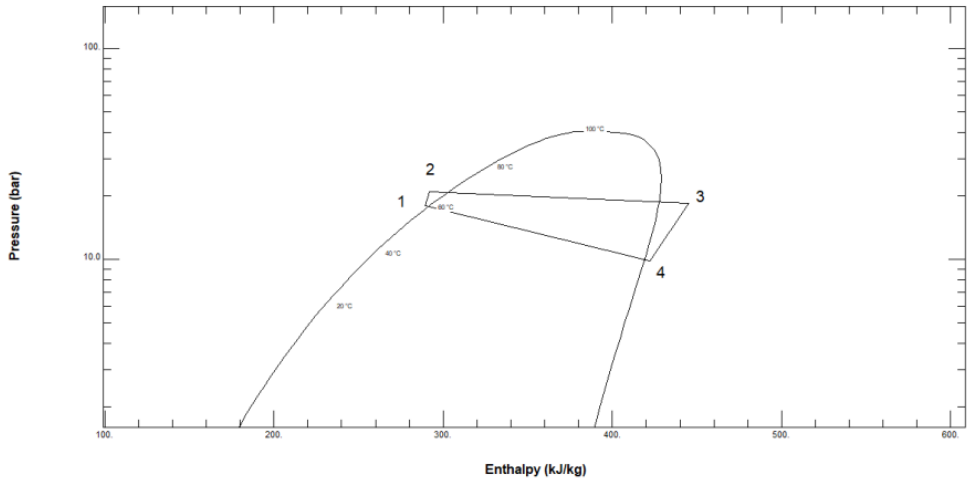

Fig 37. P-h diagram ORC test result

7. Problems and solving *Please mention problem(s) that occurred while do the research and how to solve it (them).*

The second term for the grant took a very long time, far from what was expected and until this repost is submitted term 3 has not been transferred

8. Next plan *Please mention the remaining/necessary step(s) to complete your research and expected result(s).*

- Collecting data performance of ORC between using sawdust and Pellet

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Grant FY 2022/2023

Final Report

Utilization of Hydrolyzed Palm Kernel Meal (PKM) by-products as Functional Materials for Producing Charcoal, Liquid Smoke, and Activated Carbon as a Circular Economy Model for Palm Oil Industry in Indonesia

1. Zaenal Abidin

Environmental Research Center

2. Naufal Razaan

Department of Chemistry, Faculty of Mathematics and Sciences, IPB University

3. Pramudio Pakerti

Department of Chemistry, Faculty of Mathematics and Sciences, IPB University

IPB University

Bogor Indonesia

Submitted to:

Environmental Research Center

IPB University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

November 2023

General Information

Title : Utilization of Hydrolyzed Palm Kernel Meal (PKM) by-products as Functional Materials for Producing Charcoal, Liquid Smoke, and Activated Carbon as a Circular Economy Model for Palm Oil Industry in Indonesia

Researchers:

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Bogor, 31 December 2023

Environmental Research Center,
IPB University,
Director

Dr. Yudi Setiawan, S.P., M.Env.Sc

Principal Investigator,

Dr. Zaenal Abidin, S.Si., M.Agr.

Executive Summary

Palm kernel meal (PKM) is a by-product of palm oil industry activities with abundant availability throughout the year. Currently, Indonesia is the largest producer of PKM in the world, with a production capacity of 6 million tons, and most of these products are exported. In Indonesia, A new glass wool-pyrolysis method (750 °C for 5 hours) was developed to synthesize activated carbon from palm kernel meal (AC-PKM) as an adsorbent for methylene blue. Physicochemical properties, semi-quantitative specific surface area, surface functional group profiles, and scanning electron microscopy (SEM) to reveal the characteristics of AC-PKM. The physicochemical properties of AC-PKM meet the standards set by SNI 06-3730-1995 with a semi-quantitative specific surface area of 751 m^2/g. FTIR analysis shows that the active functional groups are scattered on the surface of AC-PKM. The equilibrium data fit the Langmuir isotherm model with a correlation efficiency higher than 0,99. The highest adsorption capacity is 0.28 mmol/g adsorbent for activated carbon.

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Grant FY 2022/2023

Final Report

Design and Construction an Integrated Water Quality and Weather Monitoring System Based on Renewable Energy

1. Dr. Alvin Fatikhunnada., S.T.

PPLH IPB University

2. Dr. Liyantono., S.T.P., M.Agr.

PPLH IPB University

3. Dr. Slamet Widodo., S.T.P., M.Sc.

PPLH IPB University

4. Aras Teguh Prakasa., S.Si.Kom

PPLH IPB University

Submitted to:

Environmental Research Center

IPB University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

November 2023

General Information

Title : Design and Construction an Integrated Water Quality and Weather Monitoring System Based on Renewable Energy

Researchers:

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Institution : *PPLH IPB University*
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2 Name : Dr. Liyantono., S.T.P., M.Agr.
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3 Name : Dr. Slamet Widodo., S.T.P., M.Sc.
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4 Name : Aras Teguh Prakasa., S.Si.Kom
Institution : *PPLH IPB University*
Address of institution : Pusat Penelitian Lingkungan Hidup (PPLH-IPB) Gedung PPLH IPB, Jl. Lingkar Akademik, IPB Darmaga, Bogor, Jawa Barat, 16680, Indonesia

Bogor, 5 Desember 2023

Environmental Research Center,
IPB University,
Director,

Dr. Yudi Setiawan, S.P., M.Env.Sc

Principal Investigator,

Dr. Alvin Fatikhunnada., S.T.

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I Introduction

1.1 Background

Indonesia's commitment to supporting global climate resilience includes setting a target to reduce greenhouse gas emissions by 29% by 2030. This target is outlined in the Paris Agreement submitted to the United Nations Framework Convention on Climate Change (UNFCCC). Supporting regulations have been reflected in Law No.16 of 2016. Based on the utilization of renewable energy, the issue of water pollution is addressed due to the high levels of river pollution in Indonesia. According to the Central Statistics Agency (BPS), in 2021, 46% of rivers in Indonesia were polluted, with 32% heavily polluted, 14% moderately polluted, and 8% lightly polluted. Specific regulations, such as Presidential Regulation (Perpres) No. 15 of 2018, have been issued for key rivers like the Citarum River to accelerate pollution control and basin area damage.

The water quality parameters of rivers can change with varying weather conditions (Bhurtun *et al.* 2019). Over a more extended period, climate change also influences the alteration of surface water quality (Ivanovsky *et al.* 2016). The investigated water quality parameters may include Dissolved Oxygen (DO), pH, conductivity, nitrate, and phosphate levels. Some studies also utilize parameters such as clarity, conductivity, temperature, and water hardness to estimate the quantity of E. coli bacteria (Panidhapu *et al.* 2020).Changes in water quality are closely correlated with weather conditions, as revealed by further analysis (Safieh *et al.* 2020). This study uses weather parameters such as atmospheric pressure, evaporation, wind speed, radiation, rainfall intensity, as well as water parameters like clarity, pH, color, and E. coli bacterial content.

The IoT-based river monitoring system has been implemented (Singh *et al.* 2022), measuring approximately 17 water quality parameters transmitted using GSM. Other transmission methods commonly used for remote data transmission include radio frequency or LoRa (Santos *et al.* 2019). LoRa has regulations divided into several classes, with class B being implementable (Elbsir *et al.* 2022). Research on LoRa transmission has also been conducted by (Nakamura *et al.* 2022). However, the drawback of radio transmission is its signal range, which is not as extensive as GSM (Botero-Valencia *et al.* 2022). The combination of water quality sensors and weather stations complements each other to detect anomalies in water quality parameters. High-frequency anomaly

detection (Shi *et al.* 2018) can be performed with high accuracy up to 0.98. However, further research, particularly on the detection of pollutants, is needed, and adding weather parameters as supporting values is essential (Yoshioka *et al.* 2016). Detecting pollutants in river water can also be done from upstream to downstream (Meyer *et al.* 2019). This research discusses a monitoring system built from standard industry components with the goal of creating a system that can detect anomalies in water quality and weather parameters (Jabbar *et al.* 2022).

1.2 Problem Formulation

The design of this water quality and weather station monitoring system involves several issues that can be formulated as follows:

1. How to integrate water quality sensors and weather stations to operate in a unified manner?
2. How to design a system that can utilize renewable energy sources, such as solar panels or wind turbines, to support the operation of sensors and weather stations?
3. What is the optimal method for transmitting data to ensure information can be accessed by users, for example, through the internet or specific platforms?
4. How to present data visually so that users can easily understand the presented information?

Each of the above issues requires special attention in the system design, involving the selection of appropriate technologies, effective hardware and software design, and strategic planning of the layout of sensors and weather stations. Additionally, the user interface design should consider user needs so that the system can be optimally used to monitor and analyze water quality and weather parameters.

1.3 Objective

The objectives of this research include the following:

1. Designing a system that integrates water quality sensors and weather stations using the RS485 protocol and industry-standard sensors.
2. Developing a method to detect anomalies in the changes of water and air quality by utilizing time series graphs.
3. Designing a user interface for the sensor monitoring system.

These objectives outline the goals of the research, which involve creating an integrated system with specific protocols, implementing anomaly detection methods

using time series graphs, and designing a user interface for efficient monitoring of the sensor system.

1.4 Benefit

The aquatic environment changes due to pollutants can be monitored using this device. Monitoring will occur in real-time, allowing for immediate preventive actions and investigations into the causes if there are anomalies or if water quality changes exceed the standards. Parameters of water quality recorded in time series can serve as valuable data sources for analyzing changes in weather, water quality, or the interconnection between both. Real-time measurements prevent data changes due to chemical reactions caused by time differences, ensuring that the obtained data is factual and current. Some additional benefits include :

1. Offering precise data for water quality monitoring purposes.
2. Increasing public awareness of the significance of renewable energy and the need to be vigilant against water pollution.
3. Contributing to global efforts, as Indonesia aims to reduce emissions by 29% by 2030 in its Nationally Determined Contribution (NDC)/Paris Agreement.
4. Acting as a valuable source of information for research and educational purposes for the government, universities, and organizations.
5. Serving as a decision support system for the government in city planning and legal supremacy.
6. Encouraging the promotion of a healthier environment through water quality monitoring systems.
7. Achieving efficiency in budget and time for on-site data sampling surveys.

1.5 Scope

This research fundamentally develops a water quality monitoring system capable of detecting anomalies in water quality changes. The measured water quality parameters include EC (electric conductivity), temperature, TDS (total dissolved solids), salinity, pH, turbidity/clarity, dissolved oxygen (DO), and saturation. The weather station parameters monitored include wind direction, wind speed, air temperature, air humidity, air pressure, rainfall, and solar radiation. The interface of this system is web-based and presented in real-time time-series graphs. System analysis is conducted at each stage of design to support durability.

Data transmission in this study uses GSM and an SD card is embedded for data backup logging. The batteries employed in the system are Li-ion 18650 type with a capacity of 3000mAh each, with a voltage range between 3.6 to 4.2v. Sensor communication with the microcontroller is achieved through the serial Modbus protocol using a 5-meter cable.

II Literature Review

2.1 Water Quality Index

The quality of river water can essentially be represented by an index value measured through various parameters. According to the Minister of Environment Decision No. 115 of 2003 regarding the determination of water quality status, there are at least three groups of water parameters: physical, chemical, and biological. The Storet method is implemented to calculate the weight of each parameter, as shown in Table 1. This method works by comparing water parameter data over time with adjusted values. Initially, water parameter values are converted into qualitative values. According to the US-EPA (Environmental Protection Agency) water quality classification, the values are divided into four classes as follows:

Class A: Excellent, score = 0 => meets water quality standards.

Class B: Good, score = -1 to -10 => slight pollution.

Class C: Moderate, score = -11 to -30 => moderate pollution.

Class D: Poor, score ≥ -31 => heavy pollution.

The measurement of each water quality parameter is also regulated by established standards such as SNI 6989.57.2008 on Water and Wastewater. This standard regulates the procedures for water quality sample collection for parameters like dissolved oxygen (DO), pH, temperature, clarity, and conductivity. However, the implemented method involves sampling, which differs from real-time measurements. Water quality parameter measurements set by SNI (Indonesian National Standards) include SNI-06-6989.1-2004, SNI 06-6989.11-2004, SNI 06-6989.14-2004, SNI 06-6989.23-2005, SNI 06-4824-1998. Some studies have implemented deep learning ANN (Artificial Neural Network) methods to address anomalies in sensor readings (Sun *et al.* 2018).

2.2 Automatic Weather Station (AWS)

A weather station is a tool utilized to measure weather parameters through the atmospheric conditions of the Earth. Weather station parameters typically include temperature, humidity, wind speed, wind direction, and rainfall sensors. The data collected by these sensors is then stored and processed as input for weather prediction, historical weather analysis, and other purposes. Weather station data can also be used to calculate evapotranspiration values in an environment (Zhang et al., 2021). In agriculture, weather stations can observe microclimates, focusing on the suitability of

land conditions for specific crops. Microclimates essentially measure weather parameters in small areas.

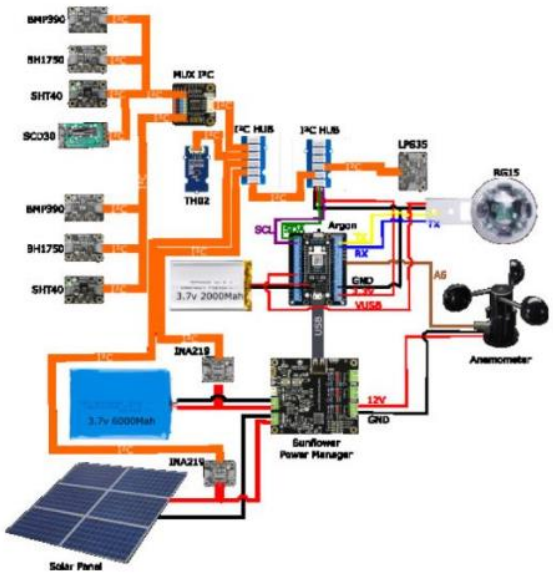

Figure 1. Schema of Weather Station (Botero-Valencia et al. 2022).

A more advanced implementation of weather stations involves combining their data with parameters measured through satellites, as proposed by (Cecilia *et al.* 2023), to determine the Urban Heat Island (UHI) effect. In this system, the values from weather stations scattered across the city are corrected using parameters obtained from satellite readings. While weather station parameters can be acquired through satellites, leveraging Global Precipitation Measurement (GPM) values, these values are not real-time and are global in nature, as discussed by (Ovando *et al.* 2021).

Weather stations store the measured parameters in memory and can also transmit them through either wired or wireless media. They can utilize transmission methods such as 3G or wifi to send data to the internet, as highlighted by(Botero-Valencia *et al.* 2022). This integration of ground-based weather station data with satellite measurements allows for a more comprehensive understanding of environmental conditions, especially in the context of studying urban heat islands.

2.3 LoraWAN

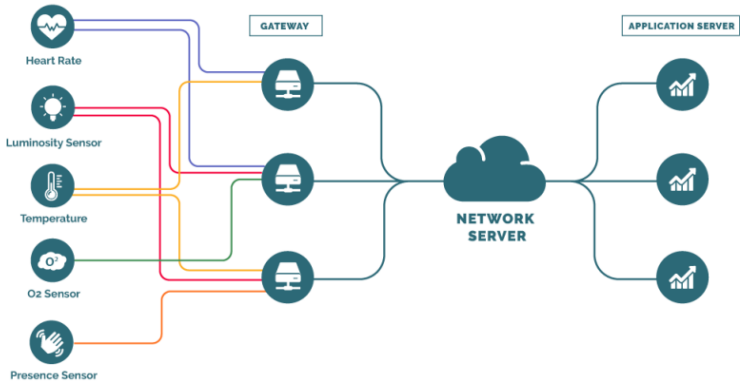

Figure 2. Schema of LoraWAN (Santos et al. 2019).

LoraWAN (Long Range Wide Area Network) is a transmission technology with low bitrate that covers a wide area. LoraWAN operates at frequencies around 433MHz and 915MHz. Frequency allocation is regulated through the Lora Alliance, and it has several classes; commonly used is class B (Elbsir *et al.* 2022). LoraWAN can be utilized to transmit data from sensors, as exemplified by air quality monitoring systems (Jabbar *et al.* 2022). IoT (Internet of Things)-based monitoring systems can be combined with LoraWAN, making the data generated by sensors more flexible.

The LoraWAN scheme consists of sensor nodes, gateways, network servers, and application servers. On the node side, sensors are embedded on microcontroller boards, responsible for transmitting data to the gateway. A gateway can be connected to more than one node, and its role is to deliver data from nodes to the network server. The network server serves as the central data receiver and provider for the application server layer. This application layer can be in the form of a web-based platform or a mobile application that displays or processes data.

The advantages of LoraWAN include its wide range, reaching a radius of more than 10km in line of sight, and its implementation can be carried out in areas not covered by GSM networks.

2.4Heltec Lora

Figure 3. Board ESP32 Heltec Lora Board.

Heltec ESP32 board is a variant of microcontrollers developed by Espressif Systems. The ESP32 is the successor to the ESP8266, and it is compatible with the Arduino IDE and MicroPython. The ESP32 microcontroller supports wireless connectivity such as Wi-Fi, LoRa, and Bluetooth Low Energy (BLE). In addition to its connectivity support, the sleep capability of this microcontroller can save power consumption down to microampere units (Guevara *et al.* 2022). The processor used is the dual-core ESP32-S3FN8 (Xtensa® 32-bit LX7 dual-core processor), making the ESP32 suitable for various applications in LoRa systems, whether as a node or a gateway.

2.5Modbus RS485 Protocol

RS485 is an asynchronous serial protocol that consists of two roles: master and slave. One of the advantages of this protocol is the long-distance it can support for data transmission, reaching up to 1.2 km. The slave's role is to provide data and has several memory registers. Meanwhile, the master's role is to retrieve values stored in the registers using specific codes. The maximum number of slaves connected to one master is typically 32, unlike RS232 communication, which supports only one slave.

In essence, the readings from sensors with RS485 interfaces are stored in a sensor's register address. The values in the register can be accessed by the master by including the slave ID and the requested register address. The slave will then respond to the request by providing the stored value in the register.

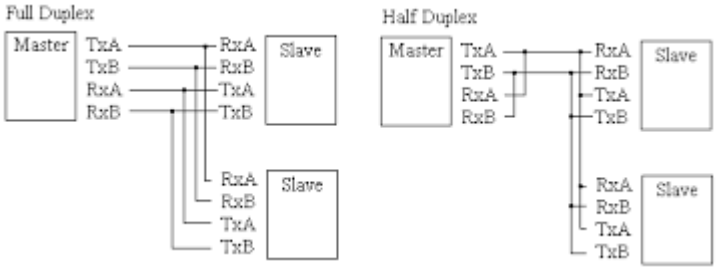

Figure 4. Schema of half duplex and full duplex.

Interface RS485 is divided into two types: half duplex and full duplex.

1. **Half Duplex:**
    - Consists of four lines: VCC (power), GND (ground), TX/A (transmit), and RX/B (receive).
    - In half duplex, each slave's TX/B line is only connected to the TX/A line, and vice versa.
    - This configuration allows communication in one direction at a time.
2. **Full Duplex:**
    - Connects each pin accordingly between the master and the slave.
    - Typically includes separate transmit and receive lines for both the master and the slave.
    - This configuration allows simultaneous bidirectional communication.

In summary, the key difference lies in the communication capabilities. Half duplex allows communication in one direction at a time, while full duplex enables simultaneous bidirectional communication.

2.6 MQTT

Protocol MQTT (Message Queuing Telemetry Transport) is a protocol specifically designed for telemetry data delivery (Shilpa et al., 2022). This protocol includes a private key that allows for encryption to enhance data security and prevent easy hacking. The

MQTT broker is responsible for validating and encrypting the data. The role of MQTT in a network can be seen in the diagram below:

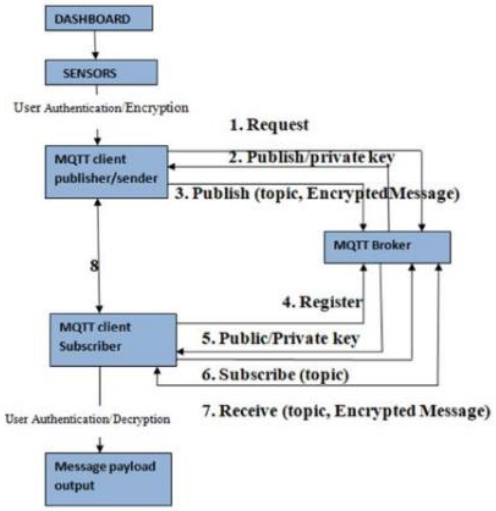

Figure 5. Flow of Protocol MQTT (V *et al.* 2022a).

First, the request will be forwarded to the sensor, and the MQTT client will send encrypted data to the MQTT broker. The broker will validate whether the request has been registered or not. Then, the private key will be sent from the broker to the MQTT client. Afterward, new data can be sent from the broker to the client, and the client can receive data from the payload.

III Methodology

3.1 Research Location and Time

The research will be conducted in the IPB Dramaga area, Bogor, at Lake LSI near the PPLH office (Environmental Research Center). The installation of equipment, including a set of sensor nodes along with photovoltaics and Lora transmitters, will be positioned beside Lake LSI IPB. The gateway device will be installed near the PPLH office, approximately 30 meters away.

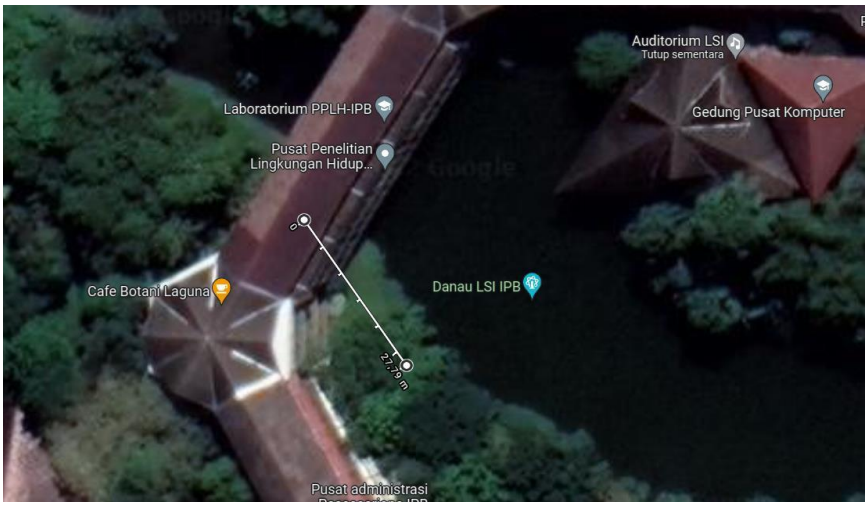

Figure 6. Research Location at IPB Dramaga.

Number of sensor nodes is 5 units, and one gateway is installed. The water quality sensors will measure parameters in Lake LSI, while the weather station will observe weather-related parameters within a distance of less than 20 meters from the water quality sensors. The instrument design is carried out in the workshop room on the 4th floor of the PPLH laboratory at Bogor Agricultural University. Photovoltaic panels are placed near the weather sensors within a distance of less than 5 meters and have a pole height of 2 meters from the ground surface

3.2 Research Tools and Materials

he required equipment for this research, aside from internet connection services, is categorized into two aspects: hardware and software. The utilized equipment is detailed in Table 1 and Table 2.

Table 1. Hardware Tools

Items	Quantity	Note

Controllino MAXI	1	Microcontroller
Heltec M0 ESP32	1	*Gateway*
Heltec ESP32 V3	1	Node sensor
Solder iron	1	
Laptop	1	
Photovoltaic 150WP	1	*Monocrystaline*
Perangkat pelampung (pipa, jerigen)	1	PVC and plastik material
Mounting and Pole	1	Allumunium material
Sensor EC RK500-13	1	
Sensor PH RK500-12	1	
Sensor *turbidity* RK-500-07	1	
Sensor DO RK500-04	1	
AWS Sensor RK900-11	1	

Tabel 2. Software Tools

Items	Quantity	Note
Arduino IDE (*Integrated Development Environment*).	1	program microcontroler bahasa c++
Microsoft Office	1	
CorelDraw	1	
Microsoft Edge	1	

3.3 Research Flow

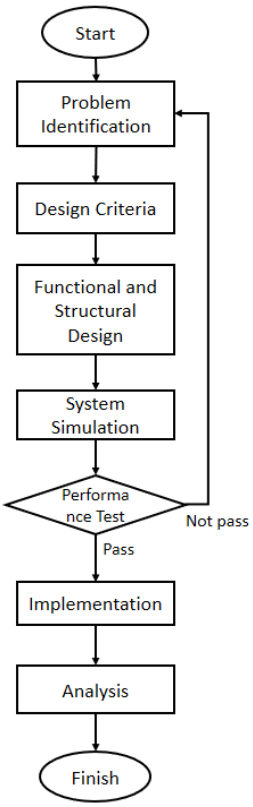

Figure 7. Research flow.

The design and construction of the device begin with the identification of the problem. Subsequently, sensor device criteria are designed to address the identified issues. The process continues with the design of the functional and structural aspects, where essential features and the working structure of the sensor device are defined. Design progresses by identifying the appropriate materials for constructing the sensor. This step is crucial to ensure the sensor device's durability outdoors.

The next steps involve simulation and calibration of the device, with calibration referencing laboratory test results to enhance sensor reading accuracy. Once calibrated, the sensor is integrated into the overall device prototype, followed by structural and functional testing. During the structural and functional testing phase, if all functions operate correctly, performance testing is conducted. If structural and functional tests yield unsatisfactory results, an evaluation of the sensor device is carried out for necessary adjustments.

Once the sensor device functions properly, performance testing and field implementation will be conducted. After completing all the aforementioned processes, the data generated by the device will be ready for analysis. The design criteria for the device to be constructed are as follows:

1. The sensor device can be powered through the installed photovoltaic system.
2. It can read water quality parameters, including EC (electric conductivity), temperature, TDS (total dissolved solid), salinity, pH, turbidity/clarity, dissolved oxygen (DO), and saturation.
3. It can read weather parameters, including wind direction, wind speed, air temperature, air humidity, air pressure, rainfall, and solar radiation.
4. It can transmit data from the sensor to the internet using LoRa transmission, with GSM as a backup.
5. The read parameters are accurately displayed through a web interface.

Materials Selected for the Project :

Tabel 3. Item Materials

No	Items	Material
1	Pole	*Iron* (*coated with anti-rust paint*)
2	Control Panel	*Plastic* IP68
3	Photovoltaic 150WP	*Monocrystaline*
4	Sensor Protector for water quality sensor	PVC
5	Weather station Sensor	ABS *Plastic water resistant*
6	Floating tube	PVC and plastic

3.4 Data Flow

The data required for this research begins with an assessment of a system. This assessment will serve as a reference for the research needs. The parameters measured in the water quality system are as follows:

1. PH
2. EC
3. Salinity
4. TDS (*Total Dissolved Solid*)
5. DO (*Dissolved Oxygen*)
6. *Turbidity*
7. Temperature
8. Saturation

While for the weather station sensor, the parameters to be measured are as follows:

1. Wind speed
2. Wind direction
3. Air Temperature
4. Air Humidity
5. Air Pressure
6. Rain
7. Rain accumulation
8. Solar radiation
9. Solar radiation accumulation

All of these parameters will be transmitted through LoRa transmission to the gateway, and then the gateway will forward them to the internet. Ultimately, the data can be accessed through a web interface by the researcher. For a more detailed data flow, please refer to the diagram below :

Figure 8. Data Flow.

Data received by the web server will be stored as a database and analyzed for anomalies. Data in the database will undergo data mining processes to identify correlations and anomalous values. Ultimately, the output will include the WQI (Water Quality Index) and the fairness value of that index. Anomalies can be identified based on the trends in the collected time series graphs, providing information on the web interface.

3.5 Design Criteria Identification

Sensor selection is fundamentally tailored to the needs of the system. The results of the sensor identification are as follows:

Tabel 4. Weather Station Sensor Criteria

Parameter	Criteria
Protokol	ModbusRS485/Analog/Digital/I2C
Power	3v, 5v, 12v (< 3W)
Protection	IP Certificate min IP 54 (Spread Air)
Weight	< 500 gram
Wind Speed	Avg BPS (0-15 m/s)
Wind Direction	Resolution 1 derajat

Solar Radiation	15.000 Lux
Rain	5000 mm (BPS-max west sumatera (2013) 4 627,40)
Temperature	0-45 degree celcius
Humidity	0-100%
Air Pressure	range 200-1100hpa

The protocol used in this research is RS485, based on the use of more than 1 unit of sensor. The RS485 protocol is a serial protocol that can accommodate up to 32 slaves. Therefore, the application of sensors can be done by adding sensors on the same line. This protocol will simplify and tidy up the wiring in the system. Other parameters, such as power for the sensor, should not exceed 3 watts to prevent excessive battery consumption. DC current is chosen for safety reasons, as the system will directly interact with water, making AC current deemed more hazardous for the research activities. The values of parameters measured by the weather station must be adjusted to the measured intervals, using the observed values from the Indonesian Central Statistics Agency (BPS) as a reference.

Tabel 5. Water Quality Sensor Criteria

Parameter	Criteria
Protokol	Modbus RS485/Analog/Digital/I2C
Power	3v, 5v, 12v (< 3W)
Protection	IP Certificate min IP 68
Weight	< 500 gram
PH	0-14
EC	0-10,000us/cm
Salinity	0-100,000mg/L
TDS	0-2000ppm
DO	0-20mg/L
Turbidity	0-3000NTU
Suhu	0-50 celsius

The requirements to consider for water quality sensors are their capabilities and lifespan. It is essential to use water-resistant sensors with valid certifications. The protocol used is the same as the weather station sensors, which is RS485. The measurement

intervals are adjusted according to BPS data to ensure that the measurements align with the original values.

3.6 Functional Design

The functions of the device to be constructed are designed to measure water quality based on predetermined parameters. The specific functions are as follows:

1. Water Quality Sensor Device:
    - Measure parameters, including EC (electric conductivity), temperature, TDS (total dissolved solid), salinity, pH, turbidity/clarity, dissolved oxygen (DO), and saturation.
    - Utilize photovoltaic technology as the primary source of electrical energy.
2. Weather Station Sensor Device:
    - Measure parameters, such as wind speed, wind direction, temperature, humidity, atmospheric pressure, rainfall, and solar radiation.
3. Node Device:
    - Transmit data through GSM to the gateway.
4. Web Accessibility:
    - Allow online access to sensor parameters.
    - Display the Index of Water Quality (IKA) for each sensor node.
    - Present time series graphs on the website.
    - Display anomaly graphs on the website.
5. Power Source:
    - Utilize photovoltaic technology as the main source of electrical energy.
6. Safety Measures:
    - Shut down the system in case of a short circuit or voltage below 12V.
7. Data Backup:
    - Implement a backup system to store data on an SD card.

3.7Identification Design

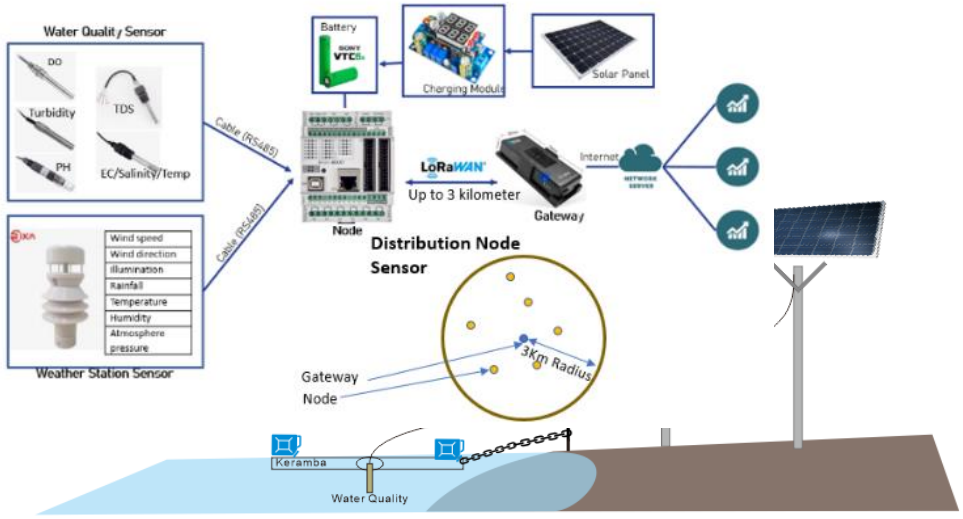

Figure 9. Schema of System.

The water quality sensors are separate and will be installed at close distances to each other. On the other hand, the weather station sensors form an integral unit that cannot be separated. In the implementation, both the weather station and water quality sensors will be positioned on the same pole and connected to a control panel. The depth of the water quality sensors will be 50cm below the water surface, while the weather sensors will be positioned at the highest point on the device. The support structure for the water quality sensors will be constructed from wood and recycled floats, resembling a floating cage that carries the water quality sensors on top. The structural layout of the device is as follows :

1. Control box: a secure space for the microcontroller and battery.
2. Aluminum pole: support for weather sensors, control box, and photovoltaic.
3. Chain/rope: ties the cage to the shore.
4. Floats: buoyancy for the cage.
5. Water quality sensors: measure parameters in the water.
6. Weather sensors: measure weather parameters.

3.8 Microcontroller Criteria

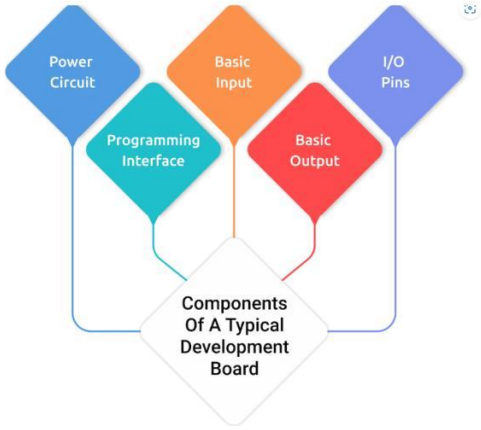

Figure 10. Component Identification.

The selection of the board is based on several considerations, including power circuit, program interface, input, output, and I/O pins. Based on the above items, the required board must meet the following criteria :

Tabel 6. Board identification

Item	Criteria
Supply power	3-5v
Programming	Arduino IDE, Micropython, .NET
Input	RS485 Modbus, Analog, Digital
Output	Led, data to cloud/lora
I/O Pin	Sensor AWS and water quality

More detail, the microcontroller board should also consider the features offered by the board. Some items that can be considered for features include memory, processing power, scalability, and connectivity capabilities. The features required for this research are:

Tabel 7. Identification of board feature

Item	Criteria
Memmory	Min 256KB> better
Processor	Min microcontroller,
Scalability	Support additional sensor and node
Transmision	Wifi, Bluetooth, Support I/O for Lora

As for other factors to consider in choosing a board, ease of purchase, price, and the availability of literature should also be taken into account. The researchers have looked at several boards available in the market, including :

Tabel 8. Avaliable Board in the market

No	Nama	Spesifikasi	Harga
1	Arduino nano IOT	ARM Cortex-M0 32-bit SAMD21 prosesor, 1 MB of Flash, 256 KB of RAM, TinyML, Bluetooth dan konektifitas Wi-Fi, Arduino IDE/Micropython	IDR 475,000.00
2	ESP32 NodeMCU	Wi-Fi & dual-mode Bluetooth, prosesor dual-core atau single-core Tensilica Xtensa LX6 clock rate 240 MHz, Memori Flash 4 MB, SRAM 520 KB, Arduino, IDE/Micropython	IDR 65,000.00
3	Pycom	LoRa, Sigfox, Prosesor dual-core, LTE-M (CAT-M1 and, NB-IoT). Konektivitas Wi-Fi (1 km), Bluetooth, LPWAN networks. 4MB RAM dan memori flash 8MB , micropython	IDR 1,500,000.00
4	Meadow F7	Psosesor STM32F7 frekuansi 216 MHZ, .NET and C#, 32MB RAM, memori flash 32MB, prosesor cadangan ESP32, konektivitas Wi-Fi dan Bluetooth, Baterai Lipo yang terintegrasi	IDR 1,500,000.00
5	Heltec Lora	Frekuensi: 915MHz, memori flash 8MB, prosesor ESP32 S3, konektivitas lora 3Km, bluetooth, wifi dan BLE, tegangan operasional :3.3v~ 7v mode wifi: sniffer,Station,softAP,Wi-Fi Direct	IDR 450,000.00

**The price is obtained from the official account of the manufacturer on the official manufacturer's website.*

Based on the list of boards above, there are several issues that arise, such as the challenge of purchasing boards that need to be imported and may take a considerable amount of time. Some boards are also not available on e-commerce platforms and may require communication with suppliers to purchase. The issue with choosing imported goods is the increase in prices due to customs duties. Certainly, this is avoided as it would raise the cost of making the tool. Therefore, the availability of goods in Indonesia is a crucial factor in this research.

3.9 Battery Requirement Analysis

Battery Capacity Requirements are adjusted according to the power used in the system. Power is supplied to energize sensors, microcontrollers, and input-output devices in the system. The battery capacity is also influenced by the duration of measurement and the interval between measurements. If the battery capacity is too small, it will result in limited operational time for the device. Conversely, if the battery capacity is too large, it must be balanced with the size of the photovoltaic system.

Measurements for each parameter are carried out serially for each sensor. The interval for each measurement is 5 minutes, with a total time required for all sensors to provide feedback being 10 seconds. If observations are made continuously for 24 hours, the daily power consumption calculation can be seen in Table 9. The power usage specifications for each component in the system are as follows :

Tabel 9. Power Calculation

Component	Qty	Power	Time (h)	Current (A)	Daily Power Consumption (Wh)
Modem GSM (5V)	1	2.5	24	0.5	60
Weather Station (12V)	1	1.7	24	0.142	40
DO Sensor (12V)	1	0.4	24	0.034	9.6
TDS Sensor (12V)	1	0.2	24	0.017	4.8
EC/Salinity Sensor (12V)	1	0.2	24	0.017	4.8
PH Sensor (12V)	1	0.2	24	0.017	4.8
Turbidity Sensor (12V)	1	0.2	24	0.017	4.8
Controllino MAXI (12V)	1	1.68	24	0.14	40.32
lain-lain	1	0.24	24	0.02	5.76
Total		7.32		0.904	175.68

Other values to accommodate wasted energy as heat, assumed to be 20mAh.

Given the total daily power requirement is 138.88Wh with measurements conducted for 24 hours without intervals. This calculation is based on the need for an adjustable or customizable interval period, allowing all devices to be active for 24 hours. Therefore, if there is no charging process by photovoltaic during the 24-hour period, the battery must still be able to activate the system.

3.9.1 Battery capacity

Based on the detailed specifications of each component in the system, assuming the system operates for 24 hours without charging, the battery capacity can be calculated as follows :

$$Battery\ Capacity\ (Ah) = \frac{Daily\ Power(Wh)}{Voltage(V)}$$

$$11.57Ah = \frac{138.88\ (\mathrm{Wh})}{12\ (\mathrm{v})}$$

The required battery capacity to handle the device actively for 24 hours is 11.57 Ah or 11,570 mAh. Based on this value, each Li-ion battery with a capacity of 3,000 mAh should be arranged in parallel in sets of 4 to represent 1 battery cell. Thus, the obtained capacity is 12,000 mAh, which is close to the needs of the built system.

3.9.2 Current Criteria

The required current in this monitoring system is based on sensor components, microcontrollers, and supporting I/O such as LEDs. The components used have been listed in Table 9, with a total current requirement of 0.6 A. Therefore, the battery used must be able to supply a current of 0.6A and a voltage of at least 12V. Based on the technical information, the Sony VTC6 battery has a maximum discharge current of 10A. This means that the system's current requirements are still below the maximum limit, and the battery used can accommodate the system's needs..

3.9.3 Battery Voltage

The battery voltage in the system is adjusted to the electronic components used. Based on Table 9, the highest voltage used by the components is 12V, while the lowest voltage is 5V. Each 18650 li-ion battery has a voltage of 3.7 to 4.2V, so at least 4 batteries need to be arranged in series to obtain a voltage greater than 12V. The total battery voltage after being arranged is between 14.4V when empty and 16.8V when full. If the

battery voltage drops below 13.8V, the device will automatically turn off to prevent damage to the battery due to excessive heat reactions.

3.10 Photovoltaic Criteria

The photovoltaic or solar panel required for the system must support fast charging, and the battery should be fully charged in less than 2 hours of sunlight in a day. However, the actual current generated by the photovoltaic system is often lower due to various factors, including changes in solar radiation caused by cloud movement or atmospheric phenomena (Ayadi *et al.* 2022). Based on BPS data for the years 2020 and 2021, the smallest average solar radiation in Bogor regency was 12.1%. This lowest value was recorded during the rainy season, specifically in February 2021. This means that during the 10-hour duration from 7:00 am to 5:00 pm, the actual sunlight exposure is not more than 1 hour and 30 minutes. The battery capacity used is 12,000mAh, and its voltage is 12V. To calculate the time needed for a full charge:

$$\text{Current system (A)} = \frac{\text{battery capacity (Ah)}}{\text{charging time (h)}}$$

$$\mathrm{I} = \frac{\mathrm{C}}{\mathrm{t}} \qquad \longrightarrow \qquad 8\mathrm{A} = \frac{12\ \mathrm{Ah}}{1.5}$$

The current value required to charge the battery fully in 1.5 hours is 8A. The photovoltaic system used should generate a current of at least 8A to ensure the battery can be fully charged within 1.5 hours. Considering the specifications of the assembled battery with a maximum voltage of 16.8V, the voltage required for the charging process must be higher than 16.8V. If the charging voltage is 18V and the current is 8A, the required photovoltaic power is 144 WP. Therefore, the photovoltaic system used in the system should have a power rating close to 144WP, which is 150WP.

IV General condition of study area

4.1 Challenge

The most challenging aspects of this research include:

1. Limited formal literacy in integrating sensor systems, microcontrollers, APIs, and interfaces.
2. Difficulty in finding durable free platforms for data transmission and interfaces.
3. The high cost of internet connectivity in Indonesia compared to other countries.

4.2Issue

1. Sensors need regular cleaning if they are covered by objects such as dirt or trash.
2. Potential leaks or damage may occur due to water or ants entering the system compartment.
3. Error values still frequently appear, and the system is not equipped with a filter to eliminate them.

V Result and Discussion

The hardware design begins with reading values from the sensors by the microcontroller. The identification of each sensor is based on the sensor's slave ID, where the slave ID is a code used as a marker between sensors. Each sensor must have a unique ID, and this ID is used during the process of requesting values from the sensor. For more details, refer to Table 5.

Tabel 5. Functional Test Result.

No	Sensor	Parameter	unit	Data Reading
1	EC RK500-13	EC (*electric conductivity*)	mS/cm	Read
2		Temperature	celcius	Read
3		TDS (*total dissolved solid*)	PPM	Read
4		Salinity	PPM	Read
5	PH RK500-12	PH		Read
6	Turbidity RK-500-07	Turbidity	NTU	Read
7	RK500-04	DO (*dissolved oxygen*)	mg/L	Read
8		Saturation	%	Read
9	RK900-11	Wind direction	degree	Read
10		Wind speed	m/s	Read
11		Air temperature	celcius	Read
12		Air humidity	%	Read

13		Air pressure	hpa	Read
14		Rain	mm/h	Read
15		Solar radiation	W	Read

The hardware components of the monitoring system are placed inside a compartment box made of ABS plastic with a cover. The compartment has dimensions of 190x290x140mm and is certified as IP66, making it resistant to fine dust and splashes of water from any direction. The components include a battery, Controllino MAXI microcontroller, 4G GSM modem, and RS485 to TTL module. All devices are connected with cables according to their respective paths, and the cables leading to the sensors are soldered with connectors. The compartment is perforated to allow the connectors to exit, with a hole diameter of 16mm in this case. The water quality sensors are mounted on a PVC pipe to protect them from impact or materials such as debris or solid objects in the water. The pipe is then perforated to allow water to pass through the sensor probe, enabling the sensor to detect changes in water quality. The complete circuit can be seen in Figure 11.

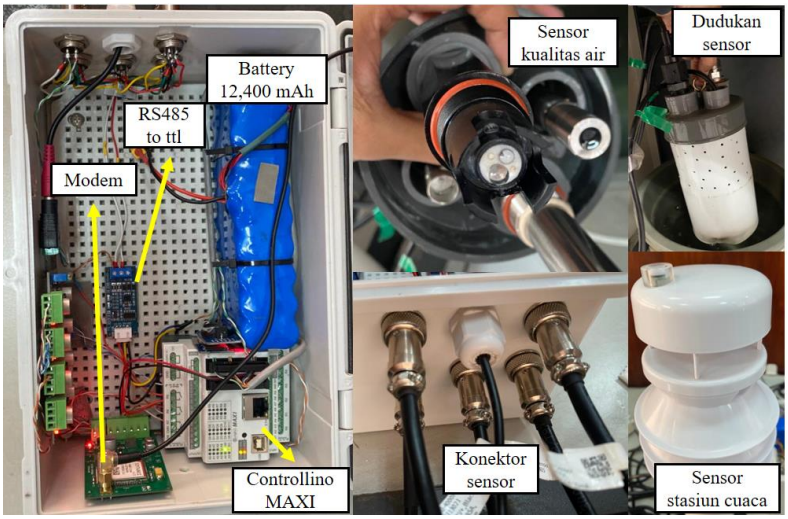

Figure 11. Hardware System.

The sensor connectors are detachable and can be interchanged with any available socket. The exchange of sockets will not affect data transmission since the sensor circuit will still follow the same path. Values are obtained by accessing the sensor ID and request code, after which the sensor will return the measured values.

5.1 Interface

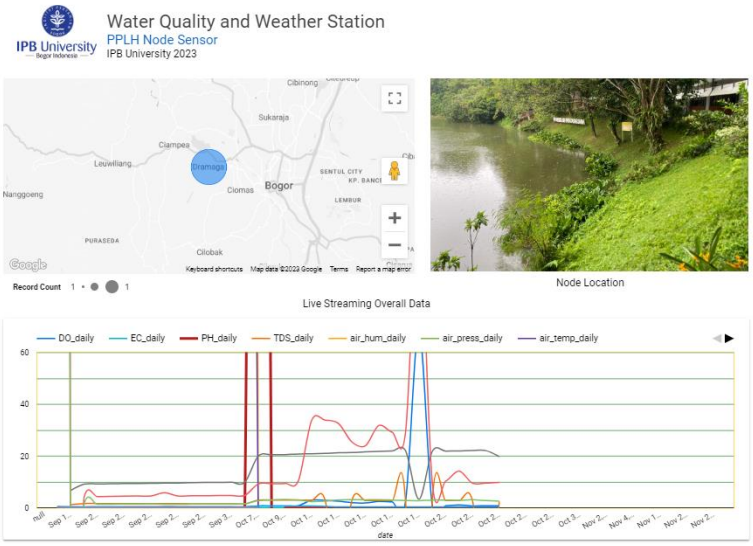

Figure 12. Homepage Interface.

The interface display is filled with the node location with a map interpretation and photos of the node's surroundings. Additionally, a time series diagram is presented to provide real-time information on parameters. A clearer view can be seen in Figure 12. Each node will have a different home display according to the coordinates where the node is placed. Users can easily identify which node is being observed and its location. The values sent by the sensors remain unchanged or rounded; errors are not eliminated or manipulated by the system. Erroneous readings result in outlier values that can be analyzed. Outlier values are caused by sensor reading errors due to incomplete data packet transmission from the sensor to the microcontroller or due to the response time of each sensor.

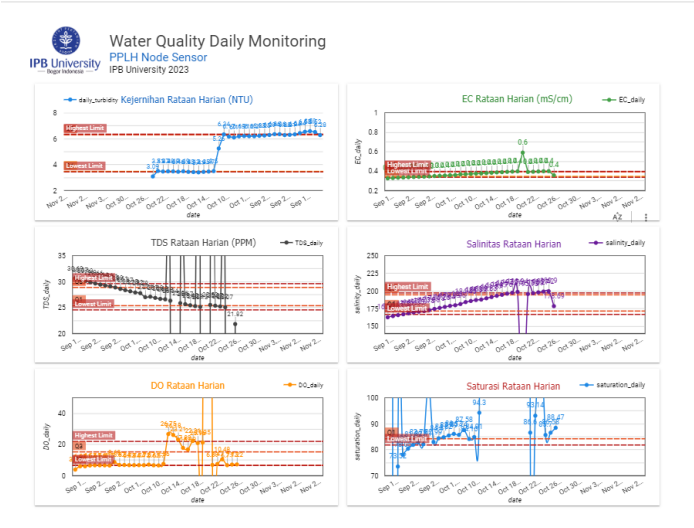

Figure 13. Graph Interface.

Each parameter read by the sensor will be available in a single time series graph, including percentile or quartile values. Quartile 1 (Q1) and Quartile 3 (Q3) values serve as upper and lower limit indicators that divide normal and anomalous values, as seen more clearly in Figure 13. Observations with a duration of 1 day will be averaged to represent daily values for each parameter. Meanwhile, observation data with a duration of every 5 minutes is still sent and stored in tabular data accessible to users. The intermediate data delivery through MQTT enhances the ease of data integration with any platform by leveraging the server for free (V *et al.* 2022). An example of the resulting tabular data can be seen in Figure 14, and the same information is also copied to the sdcard for data logging embedded in the system.

.

	A	B	C	D	E	F	G	H
59967	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":16	lue":2	"rtc'	16	29.20	2023/10/17
59968	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":15	e":211	"rtc'	15	211.53	2023/10/17
59969	{"id":"PPLH001","ids":1	{"id":"PPLH001"	"ids":17	/alue":	"rtc'	17	0.00	2023/10/17
59970	{"id":"PPLH001","ids":1	{"id":"PPLH001"	"ids":11	e":25.2	"rtc'	11	25.28	2023/10/17
59971	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":10	ue":0.3	"rtc'	10	0.40	2023/10/17
59972	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":12	ue":29	"rtc'	12	29.51	2023/10/17
59973	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":13	ue":19	"rtc'	13	197.75	2023/10/17
59974	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":18	e":3.39	"rtc'	18	3.39	2023/10/17
59975	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":14	e":16.	"rtc'	14	16.38	2023/10/17
59976	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":16	lue":2	"rtc'	16	29.20	2023/10/17
59977	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":15	e":212	"rtc'	15	212.87	2023/10/17
59978	{"id":"PPLH001","ids":1	{"id":"PPLH001"	"ids":17	/alue":	"rtc'	17	0.00	2023/10/17
59979	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":10	ue":0.3	"rtc'	10	0.40	2023/10/17
59980	{"id":"PPLH001","ids":1	{"id":"PPLH001"	"ids":11	e":25.	"rtc'	11	25.10	2023/10/17
59981	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":12	ue":29	"rtc'	12	29.53	2023/10/17
59982	{"id":"PPLH001","ids":1:	{"id":"PPLH001"	"ids":13	ue":19	"rtc'	13	199.20	2023/10/17
59983	{"id":"PPLH001","ids":1(	{"id":"PPLH001"	"ids":18	e":3.39	"rtc'	18	3.39	2023/10/17

Figure 14. RAW Data.

The data transmission format through the MQTT server includes the node name, sensor ID, RTC (Real-Time Clock), and the sensor reading value. The RTC value used as a reference is the time when the sensor receives the request command for parameter value. Subsequently, this time value is also sent as part of the data payload. Thus, the displayed time represents the sensor reading time, not the time the data is received by the server.

VI Conclusion and recommendation

6.1 Conclusion

After designing the device as planned, the following conclusions were drawn:

1. The design of the water and weather sensor monitoring device can be implemented using the RS485 Modbus protocol and an industrial standard microcontroller, Controllino.
2. Data transmission using an MQTT server can be achieved, and the data can be accessed graphically or in tabular form.
3. Data backup system can be implemented using an SD card as a data storage medium.
4. Additional information to assist in the analysis of data anomalies can be displayed on the interface graphs.

6.2 Recommendation

Recommendations to enhance the capabilities of this device include:

1. Add an alert system integrated with mobile devices and email to provide notifications when parameters exceed normal limits.
2. Improve the mounting mechanism for safer measurements in fast-flowing environments.
3. Enhance power efficiency by using low-power industrial-standard microcontrollers.
4. Develop a minimalist system to reduce the device's dimensions, making it more flexible for installation.

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Research Grant FY 2022/2023

Final Report

Development of WebGIS Application for Mapping Potential of Rice Husk as Biomass Cofiring Material in Power Plants

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I. Introduction

1.1 Backgtound

The use of fossil energy, oil and gas nationally dominates at 91% (IESR 2021), which is a challenge for Indonesia in achieving the new and renewable energy mix target of 23% by 2025 and the greenhouse gas (GHG) emission reduction target of 29% by 2030. Meanwhile, until the end of 2019, the implementation of renewable energy had only reached 9.15%, of which 6.2% came from renewable energy plants and 2.95% came from biofuels (biodiesel) (BPPT 2021). One of the sources of EBT is biomass where the potential of biomass still needs to be developed. KESDM (2020) stated that only 5.6% of biomass potential has been utilised or only 1,889.8 MW. In addition, Indonesia has currently begun to implement biomass cofiring technology through initiation at PT Perusahaan Listrik Negara (PLN) in early 2020 and has been implemented in 32 locations, which is 63% of the implementation target in 2025. According to DMPEBT (2022), the programme has generated up to 487 MWh of green energy, of which 296 MWh in 2021, and 218 MWh in January-May 2022. This technology is considered to be one of the alternatives in increasing the national renewable energy mix.

Biomass cofiring is defined as the technology of substituting coal with biomass fuel at a certain ratio. Various parties consider the supply of biomass feedstock as the main challenge to maintain the sustainability of the biomass cofiring strategy. According to the Director General of New, Renewable Energy and Energy Conservation (DJEBTKE) (2021), the biggest challenge in the implementation of biomass cofiring is the effort to maintain the sustainability of biomass feedstock supply while still considering the economic aspects so as not to exceed the cost of generation. Several biomass materials such as sawdust, wood chips, corn cobs, rice husks, and solid recovery fuel (SRF) have been utilised by PLN. Rice husk as a biomass energy source has promising potential as Indonesia is the fourth largest rice producer after China, India, and Bangladesh (Databoks 2022). However, information on its availability is still lacking. In fact, BPS (2021) shows that 66.48% of

rice milling units do not have production records. This shows that there is insufficient information to measure the potential of the husk produced, so it needs to be researched and how its potential in supplying biomass needs for cofiring in power plants.

Studies and research on the potential of rice husk based on biomass cofiring strategies and availability at each rice mill location are also lacking. Research from Dewi and Ardhitama (2020) and Sudia et al. (2020) resulted in a rice husk potential of 3,274 GJ/year and 1,700 GJ/year, respectively, in the case study areas of Magelang and Southeast Sulawesi. The research results only mention the amount of biomass potential, but the utilisation of this potential has not been comprehensively identified. In addition, information on the use of rice husk and its distribution to certain parties is also not widely available, which can be used to determine the real potential of rice husk biomass. Therefore, this research will focus on collecting data and information on rice husk availability using a geographical approach through the development of geographical information system applications of spatial and tabular information. Spatial analysis followed by economic analysis is chosen to identify the potential of rice husk through information on the distribution of rice husk availability locations.

This research will focus on Indramayu Regency, West Java Province as a pilot research location because it is the regency with the most rice production in 2020 and is the location of a power plant that has implemented biomass cofiring. The availability of rice husk information that will be carried out in this research is expected to be the basis for decision making for PLTU related to the fulfilment of biomass needs.

1.2 Problem Statement

Reducing the use of fossil fuels is a challenge for achieving the renewable energy mix target and can be addressed by one of them through the implementation of biomass cofiring technology. This technology utilises biomass as a partial substitute

for coal to be burned in power plant boilers. The implementation of this technology has been started from the beginning of 2020 by PT PLN (Persero) but there is a major problem, namely the availability of biomass to ensure the sustainability of its implementation. Meanwhile, biomass is abundantly available and according to the mapping results of the Directorate General of New, Renewable Energy and Energy Conservation (EBTKE), waste from rice husks reaches 10 million tonnes. This research will focus on rice husk biomass and its potential to supply the needs of biomass cofiring technology through a geographical and economic approach. The challenge of providing sustainable biomass supply can be supported by information related to the potential of rice husk in rice production centres such as Indramayu Regency. This research will collect data and information to obtain a spatial and tabular overview of the potential of rice husk.

1.3 Objective

This study aims to spatially analyse the availability of rice husk as a raw material for cofiring supply at power plants in Indramayu.

1.4 Benefits

The benefits of this research are as follows:

1. The utilisation of husk waste as cofiring raw material can be an alternative solution for rice milling businesses to gain more economic value.

2. Access to information on the potential of renewable energy from location-based rice husk waste can be available on the internet for both rice milling business actors, power plants and related parties.

3. Creating employment opportunities through industry in the field of biomass management.

The benefits of this research are as follows:

1.5 Research Scope

This research has several scopes as follows:

1. The research was conducted in Indramayu Regency as a case study location
2. The biomass used is rice husk biomass.
3. The main target in this research is the location of rice mills ranging from small, medium, and large scale as the supply centre of rice husk
4. Related information refers to the time of data collection, namely, during February-May 2023.

II. Literature Review

2.1 Biomass Cofiring

Biomass can be broadly understood through the UNFCCC (2005) definition that biomass is non-fossilised and biodegradable organic matter derived from plants, animals and microorganisms. Biomass also includes primary and by-products, residues and wastes from agriculture, forestry and related industries as well as non-fossilised and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids obtained from the decomposition of non-fossilised and biodegradable organic matter. Meanwhile, cofiring is the burning of two (or more) different types of materials at the same time. When it comes to cofiring in power plants, cofiring is defined as a short-term, low-cost option to efficiently and cleanly convert biomass into electricity by adding biomass as a partial replacement fuel in high-efficiency coal boilers. Biomass cofiring is the process of adding biomass as a partial replacement fuel in coal boilers in power plants.

According to DMPEBT (2022), the demand for biomass as a substitute for coal reaches 10.2 million tonnes/year. This demand can be accommodated by the untapped potential of biomass. This is related to the National Electricity General Plan (RUKN), where PT PLN (Persero) will implement biomass cofiring in 52 PLTU units until the year with a total capacity of 18,154 MW. Currently, biomass demand reaches 450,000 tonnes by 2022 and is expected to increase by 2.2 million tonnes by 2023. Biomass cofiring schemes at several percentages and feedstock requirements are shown in Table 1. The availability of unutilised rice husk could answer the need for biomass as cofiring material in power plants. However, this still depends on the specific location of each potential husk as transportation costs are a major consideration in determining the economic feasibility of rice husk utilisation.

Tabel 1 Biomass demand in several biomass cofiring scenarios (Muhajir 2022)

Biomass cofiring percentage (%)	Biomass demand (ton)
1	1.022.868
5	5.114.340
10	10.228.679

2.2 Rice Husk Potential

Data from Sudia et al. (2020) showed that the fraction of rice husk as waste in the rice milling industry is 20-23% in addition to rice bran which has a fraction value of 8-10% of the total mass weight of milled dry grain (MDG). The calculations and analyses in this paper will use a fraction of 20% which is mostly used and referred to from various sources as in Table 2.

Table 2. Fraction of rice husk waste according to some sources

Source	Discussion Scope	Rice Husk Fraction
Dhankhar (2014)	Rice milling	20%
*NRR (2016)	Rice milling technology	20%
*IRRI (2016)	Rice milling by-products for alternative agricultural and food applications	20%
Pujotomo (2017)	Potential of rice husk biomass as power generation through gasification	22%
Dewi dan Ardhitama (2020)	Study of rice husk as alternative energy	22%

*NRR: New Rathna Rice, IRRI: International Rice Research Institute

According to BPS (2022) in Dataindonesia (2022), the national rice production in 2021 is 54.41 million tonnes of milled dry grain (GKG). This value has the potential to produce around 10.88 million tonnes of rice husk. Figure 1 shows rice production in Indonesia on a GKG basis.

The biomass potential of rice husk in Indramayu Regency, based on the production of rice in GKG of 1.36 million tonnes, is around 272,000 tonnes. The power plant in Indramayu, PT PLN Nusantara Power UBJOM PLTU Indramayu, has a generating capacity of 3x300 MW. Until now, the government has implemented biomass

cofiring with a 1-10% mixture scheme implemented in the PLTU Cofiring Plan in 2021. Referring to Aprilla's research (2022), biomass demand in Indramayu reached 931.5 tonnes/day or 338,445 tonnes/year. Theoretically, this demand can be met by 80.34% by maximising the potential of rice husk biomass in Indramayu Regency. However, the lack of information and the problem of many rice mills that do not have production records are major obstacles in mapping the real potential of rice husk in this area.

Rice mills in Indramayu Regency are the main reference point in efforts to provide the potential of rice husk as a cofiring material through a geographical approach. According to BPS (2021) in the 2020 Directory of Rice Milling Industry Businesses/Companies, as many as 1616 rice mills have been operating in Indramayu Regency. This number of rice mills is divided into 1,340 small-scale, 207 medium-scale, and 69 large-scale. In the same report, the executive summary section explains that small, medium, and large-scale rice mills are differentiated based on rice production capacity as shown in Table 3. The capacity per day is calculated with the assumption that operating hours per day are eight hours. Data on the rice milling industry in Indramayu Regency is presented in Appendix 1 and Appendix 2 which shows the number of rice mills in each sub-district and a visual map of their distribution.

Table 3. Classification of rice milling businesses based on rice milling capacity (tonnes of rice/hour)

Scale	Capacity (ton rice/hour)	Capacity (ton rice/day)
Kecil	<1.5	<12
Menengah	1.5-3	12-24
Besar	>3	>24

2.3 Geographic Information Systems (GIS) and Spatial Data

A set of geospatial data management, visualisation and analysis capabilities have been developed since 1962. Research on the use of geographical information system (GIS) technology is increasing today because of its main function in

processing and presenting data and information that is easily understood by researchers or related parties in need. ESRI (2016) explains that GIS is a system of hardware, software, and procedures that capture, store, edit, manipulate, manage, analyse, share, and display georeferenced data. Andreev (2020) stated that GIS technology is a progressive and convenient way of presenting data to consumers where users can access specific location map information simply by downloading an application on a mobile phone. According to Steinitz (1990) and Dangermond (2009), GIS offers a set of analytical functions that can reveal relationships, patterns, and trends that are not easily visible, allowing people to think spatially in solving a problem and ultimately making smart decisions.

This technology basically utilises spatial data which is geo-referenced data that will be processed using software and hardware through a series of methods and analyses to be displayed in a computer-based system. According to Guptill (2001), spatial data includes all data sets such as digital cartographic data, remote sensing images, and census tract descriptions, as well as more specialised data sets such as seismic profiles, the distribution of relics in an archaeological site, or migration statistics. Basically, spatial data is divided into vector data and raster data where vector data displays, locates, and stores spatial data in the form of points, lines or curves, or polygons along with their attributes. Attribute data is data in the form of descriptions that are usually presented in tables as a form of more detailed information. Meanwhile, raster data includes a matrix or pixel structure that forms a grid. According to Osgeo (2013), the utilisation of these two spatial data is adjusted based on their needs. Figure 2 below shows the difference between vector data and raster data.

2.4 Spatial Analysis

According to ESRI Dictionary (2023), spatial analysis is the process of examining the location, attributes, and relationships of features in spatial data through overlays and other analytical techniques to answer questions or gain useful knowledge. This

research will utilise the Quantum GIS version 3.22.12 application as a tool to process the spatial data obtained from this research.

III. Method

3.1 Location and Time of Research

This research will be conducted from July to October 2022 and will take place in Indramayu Regency and the Bioinformatics Engineering Laboratory, IPB. Figure 3 below shows the location of the sampling data, namely the administrative map of Indramayu Regency. The total area reaches 2,099.42 km2 with a total of 31 sub-districts and 317 villages.

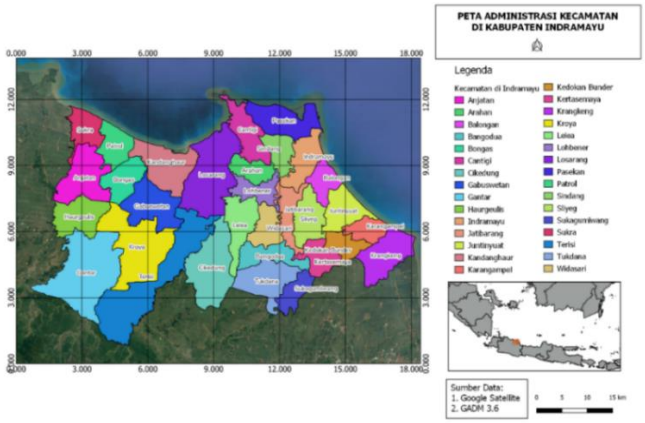


Figure 3 Research location map

3.2 Location and Time of Research

The data required in this study are primary data from field observations and secondary data collected from government and spatial data provider websites. The primary data was in tabular form while the secondary data was in the form of vectors and satellite images (Table 4). The tabular data was inputted into the database and then merged with the vector data.

Table 4 Research data and sources to obtain it

No	Data	Type	Source
1	Rice mill data Indramayu Regency Tabular BPS West Java	Tabular	BPS West Java
2	Rice mill coordinates	Tabular	Field Survey

3	Biomass availability	Tabular	Field Survey
4	Price and processing cost	Tabular	Field Survey
5	Rice mill distribution map	Vektor	Indonesia Geospasial
6	Administration map	Vektor	BIG*
7	Field map	Vektor	KEMENTAN*

*BIG: *Badan Informasi Geospasial,* KEMENTAN: *Kementerian Pertanian*

3.3. Research Procedure

This study aims to analyze the availability of rice husk in Indramayu Regency using spatial and economic approaches. The analysis requires the utilization of the QGIS 3.22.12 application as well as direct data collection through surveys and interviews with rice mill managers. Related stages that must be carried out during the research process are shown in the research flow chart in Figure 4.

3.3.1. Literature Review

The literature study was conducted to explore data and information that had previously been conducted by researchers and writers regarding the spatial and economic distribution of rice husk availability. This stage aims to understand the potential and problems that become the background of the problem of why this research needs and is possible to do.

3.3.2. Primary Data Collection

Primary data collection is carried out by field surveys and interviews where the main primary data to be collected are location coordinates, data on husk prices at each rice milling location and factors that can affect prices and changes including but not limited to transportation modes for transporting husks and distribution of husk use to certain parties.

3.3.2.1. Determination of Primary Data Eligibility

Primary data collected from this study consisted of coordinate data, price and availability of husk, transportation mode and transport capacity as well as

documentation obtained from surveys and interviews. Coordinate data was obtained by using Locus and Google Maps applications to mark the coordinate points of rice mills. The price component is the primary data that forms the basis for the economic analysis of the availability of husk for cofiring. With regard to the feasibility of using biomass waste as fuel, DMPEBT (2022) determines three sources of biomass price components, namely:

1. Biomass Feedstock

   Abundant biomass fuel potential sourced from full and partial organic materials that require processing or no processing.

2. Biomass Processing

   Biomass processing into pellets requires industrial development with investment

3. Transportation

   Feasible distance is <100 km from the raw material source without processing or industry.

This research will use the third component source as a reference for primary data collection where rice mills in Indramayu Regency will be collected from the starting point, namely PLTU Indramayu, to the location points of rice mills. Table 6 shows the distance and travel time from PLTU Indramayu to the sub-district administrative boundaries in the north, south, east, and west of Indramayu where data was collected through the Google Maps application. The data shows that in each sub-district, all rice milling locations fall within the feasibility distance specified by the DMPEBT with the longest travel time being 1 hour 47 minutes. Therefore, all rice mill locations in Indramayu are feasible as source locations for the availability of rice husk biomass for the Indramayu PLTU.

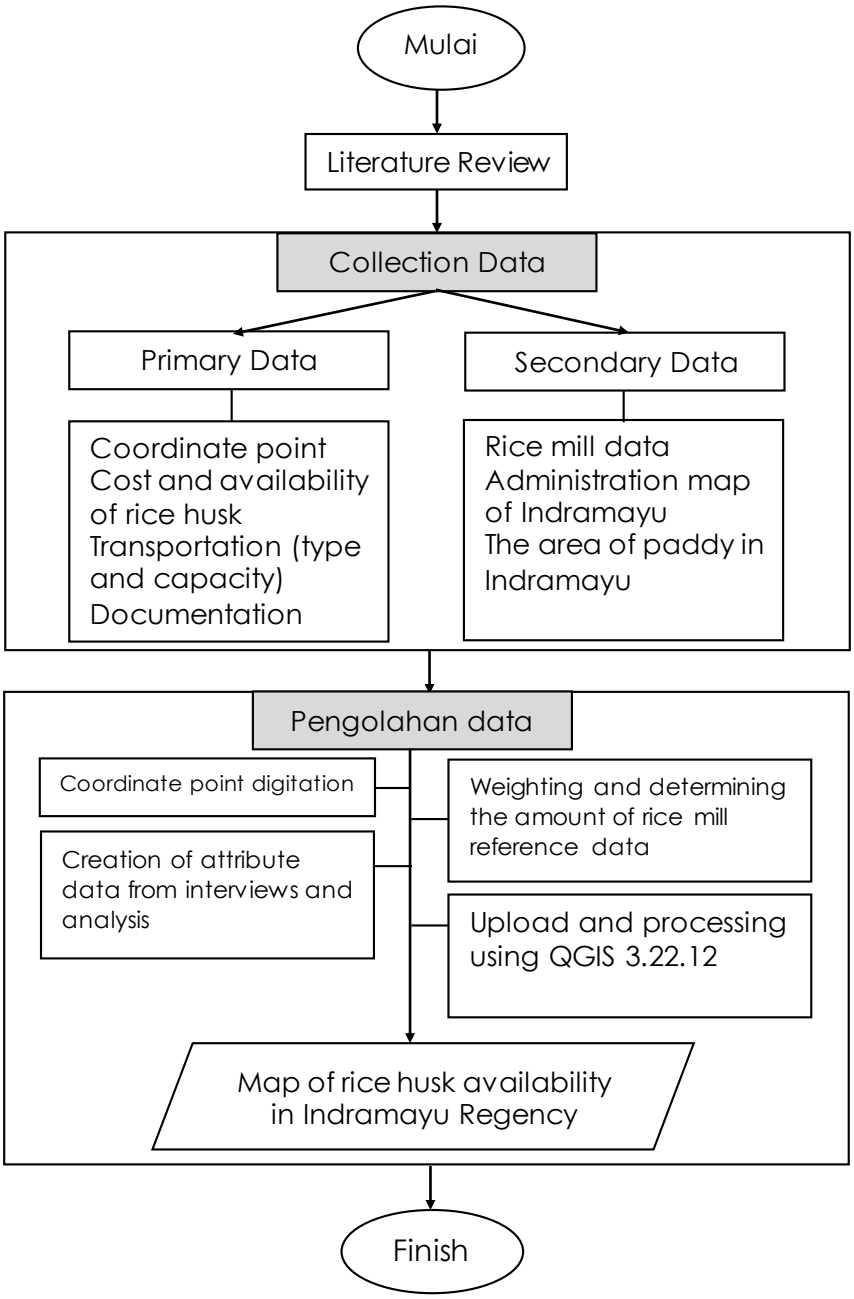


Figure 4 Diagram alir penelitian

Tabel 6 Table 6 Distance and travel time of Indramayu power plant to sub-district boundaries in four cardinal directions

Boundary Subdistrict Cardinal Direction	Distance from Indramayu PLTU (km)	Travel time
North		
Cantigi	54,4	1 hour 15 minutes
Pasekan	58,1	1 hour 18 minutes
Losarang	32,1	41 minutes

South		
Sukagumiwang	69,0	1 hour 27 minutes
Tukdana	60,3	1 hour 15 minutes
Cikedung	49,2	1 hour 17 minutes
East		
Anjatan	15,5	27 minutes
Haurgeulis	25,8	47 minutes
West		
Karangampel	72,1	1 hour 33 minutes
Krangkeng	78,4	1 hour 40 minutes
Juntinyuat	69,2	1 hour 26 minutes

3.3.2.2. Sample Scope

Primary data to be collected is carried out by the incidental sampling method where the data entering the sample is surveyed randomly and not predetermined. According to Sugiyono (2016), the incidental sampling technique is to determine any patient who happens to meet the researcher can be used as a sample, if it is considered that the person who happened to be met is suitable as a data source.

Determination of the number of samples of the data collection is 10% of the population (1616 rice mills), thus the sample number of this research is 161 rice mills.

3.3.3. Secondary Data Collection

Secondary data collected by researchers includes the collection of secondary data and information available as basic material for the next stage such as collecting data on the distribution of rice mills according to BPS, rice distribution maps from KEMENTAN, and administrative data of Indramayu Regency at the Geospatial Information Agency (BIG).

3.3.4. Secondary Data Collection

Data processing is divided into primary and secondary data processing, each of which is equipped with methods and data analysis after processing the data as follows.

3.3.4.1. Coordinate Digitation

Coordinate data as the main primary data has been obtained using the Locus and Google Maps applications. Locus is used as a coordinate data retrieval in the field and Google Maps as a correction or validation. The data collected was entered into one data in a Microsoft Excel document as a coordinate database.

3.3.4.2. Weighting and Determining the Amount of Reference Data

The weighting was done to adjust the sample data proportional to the total population of rice mills in each scale. The resulting values at each weighting were used as a reference database to calculate the averages needed for identification and analysis.

3.3.4.3. Attribute Data Processing

Attribute data is qualitative data and information added into Microsoft Excel as a basis for analyzing the availability of husk and other phenomena found to be associated with each milling scale and the availability of rice husk. The additional data was obtained from interviews.

3.3.4.4. Uploading the Attribute Data

The processed attribute data was saved in csv (comma-separated values) format and uploaded to the Quantum GIS (QGIS) application version 3.22.12 and processed to describe the spatial distribution starting from the distribution of sample data points, the distribution of rice husk availability, and the density of husk availability in Indramayu Regency.

3.4. Availability Analysis

The potential of rice husk is analyzed from several assessment parameters consisting of theoretical potential, mobilizable potential, and energy potential, and accessibility of rice husk biomass. In this study, the assessment will be carried out up to the mobilizable potential stage because the intended form of material is still in

bulk form, namely rice husk. The overall analysis refers to Figure 8 where the availability of agricultural biomass is assessed on each parameter. This assessment approach was adapted from Barry et al. (2022).

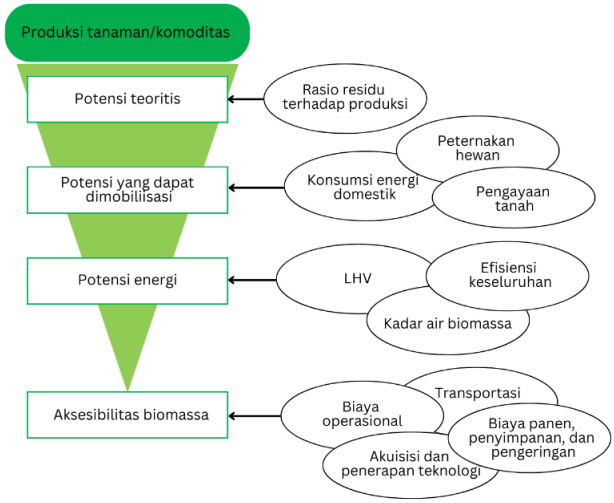


Figure 5 Assessment level of agricultural biomass availability Barry et al. (2022)

IV. Result and Discussion

4.1 Overview of Rice Mill in Indramayu

Rice milling is one of the supply chains of grain-to-rice processing that starts from rice producers (farmers), collectors or middlemen, and rice mills. Most rice mills in Indramayu follow the chain pattern for rice starting from farmers, collectors, rice processing industries, wholesalers, retailers, and final consumers. According to BPS (2021), rice mills become the meeting center between production, processing, and marketing which is important and strategic. The potential and processing of rice husk as a by-product or waste of rice milling depends only on the rice milling process. Figure 10 shows the flow of post-harvest rice processes and products up to the rice mill adapted from Salsabilla et al. (2014), Sudia et al. (2020), and BPS (2022). The value of 20% is used as a multiplier of the rice husk potential at each rice mill taken from various related studies.

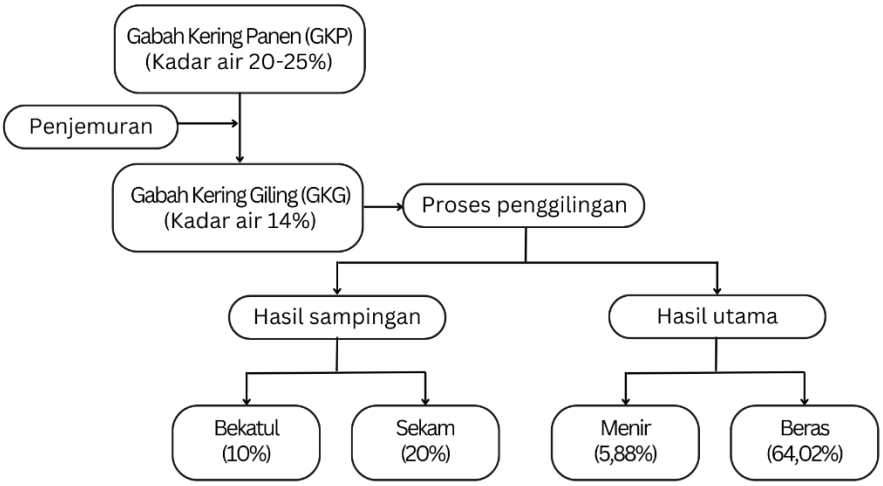


Figure 6 Rice post-harvest product and process flow

Indramayu Regency has a total of 1,616 rice mills distributed in 1,340 small-scale mills, 207 medium-scale mills, and 69 large-scale mills. This number is lower than the number of rice mills in 2012, which was 1,786. This shows that within eight years there was an overall reduction of 120 rice mills. This reduction indicates that the availability of rice has also decreased. According to BPS (2021), a decrease in the

number of rice milling industries indicates a potential reduction in rice availability. This can also affect the availability of husk in calculating its potential in a region.

However, the large number of mills can also create competition in obtaining grain raw materials which can cause the price to be expensive (Firdaus 2018). Therefore, adjusting the number of mills to the production capacity of Indramayu Regency level also needs to be considered so that the price of grain can still be competitive for the parties in the grain-to-rice supply chain, especially the rice mill managers. Determinations related to the suitability of the number of rice mills nationwide have been made by the Indonesian Rice Milling and Rice Entrepreneurs Association (PERPADI) with three alternative scenarios of the ideal number of rice mills at each scale. According to PERPADI (2014), the number of rice mills, especially small-scale ones, should be cut in balance with grain production. Reducing the number of rice mills can automatically reduce competition for raw materials. In addition, Rachmat (2012) examined the integrated milling model as a solution to increase added value in the form of improving the quality and yield of rice in rice mills.

Figure 7 shows the change in the number of rice mills in 2012 and 2020 in each sub-district in Indramayu.The figure shows that although there was an overall decrease, there were several sub-districts that experienced an increase in the number of rice mills such as Anjatan, Balongan, Cantigi, Karangampel, Lelea, Losarang, and Patrol.This increase can be influenced by the main factor, namely the increased harvest area.Related data can be seen in Appendix 4 where the data displayed is the result of processed BPS data for Indramayu Regency in 2012 and 2018 regarding rice commodities.Based on Appendix 4, it is evident that the increase in harvest area occurred in six sub-districts so that the increase in the number of rice mills is directly proportional to the increase in rice harvest area.However, the harvested area in Lelea sub-district is of the same value with even lower productivity and production values. It is suspected that the demand for grain mills increased from areas near Lelea sub-district with high harvest areas such as Cikedung sub-district where the number of mills decreased but the harvest area

increased from 2012 to 2018. Appendix 5 shows a map of harvest areas that can facilitate the conjecture in this study.

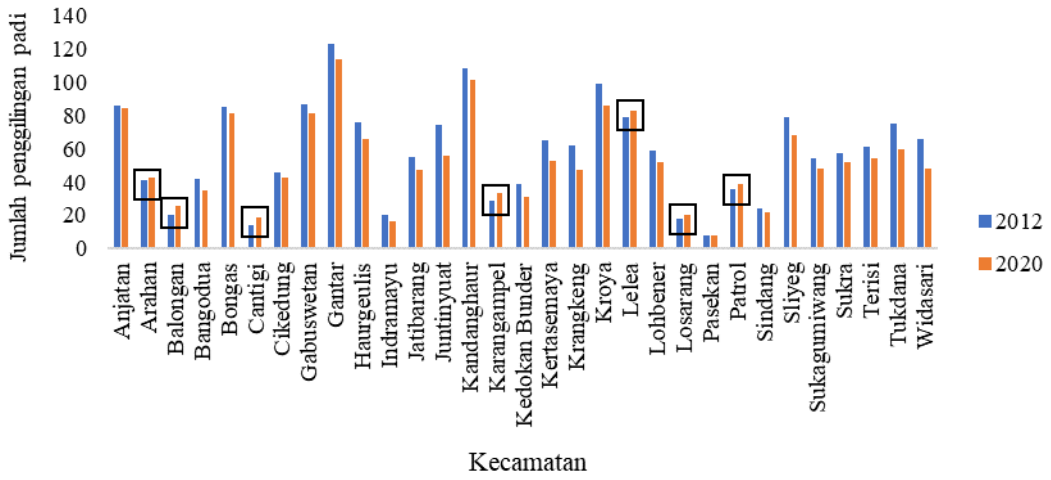


Figure 7 Development of the number of rice mills in 2012 and 2020

Rice mills in Indramayu operate on average for 4 days a week with each operating for 4 days at the small scale, 5 days at the medium scale, and 6 days at the large scale. However, the mills do not operate on public holidays and holidays.The production duration of a mill affects the amount of estimated rice husk potential calculated.This is because each mill has a daily production capacity that will be accumulated in units of years so that the estimated length of production is important to consider.Annual production days are divided based on harvest and non-harvest periods.The harvest period in Indramayu occurs around April and October each year and the other months are non-harvest periods.The calculation of the annual production days of the rice mill can be seen in Table 7. This value will be used as the basis of the chaff potential multiplier to obtain the potential in harvest and non-harvest periods.

Tabel 7 Perhitungan hari produksi penggilingan padi dalam satu tahun

Mill Scale	Production Day	
	Harvesting Season	Non-harvesting season
Small	52	40
Medium	60	200
Large	60	240

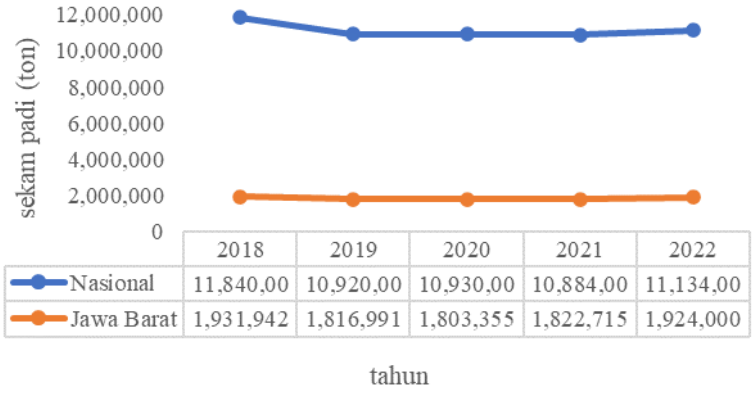
Production records are vital in estimating the performance of a rice mill. It is also an accurate basis for researchers to determine the potential of rice husk. However, as many as 66.48% of rice mills in Indonesia do not have production records (BPS 2021) which makes it difficult to monitor the development of production in terms of quantity. Based on the data and information obtained, 70.53% of small-scale rice mills do not have production records. This is because most small-scale millers feel that record-keeping is less effective due to the unpredictability of milled grain. Meanwhile, medium and large-scale rice mills as a whole have production records.

This production record is also related to the fact that there are too many rice mills, so those with high efficiency are able to produce. Small-scale rice mills are the most affected in this case. Therefore, the government needs to launch a revitalization of rice milling on three main pillars, namely technology, institutions, and financing or capital (PERPADI 2022). Revitalization of rice milling is expected to be able to support the problems of small-scale rice milling not only through capital assistance and facilities but also assistance in ensuring the sustainability of the rice processing industry.

4.2 Rice Husk Availability Development

The development of rice husk availability in general can be seen from data on rice production in milled dry grain (MDG) in Indonesia which is calculated from the rice husk ratio of 20%. Figure 12 shows the development of rice husk availability at the national level and West Java Province over the last five years where production data is sourced from the Central Bureau of Statistics and the Ministry of Agriculture. The development at the national level shows fluctuating values every year while at

the West Java Province level from 2018 has decreased until 2020 and then increased until 2022. The increase in the amount of rice husk shows an average percentage increase of 3.84% or 71,041 tons of rice husk each year. This indicates adequate husk potential that can be utilized for its sustainable use in West Java.



	2018	2019	2020	2021	2022
Nasional	11,840,00	10,920,00	10,930,00	10,884,00	11,134,00
Jawa Barat	1,931,942	1,816,991	1,803,355	1,822,715	1,924,000

Figure 8 Rice paddy production over the last five years at the national and West Java Province

The quantity of rice husk in a region is influenced by the rice production practices of farmers and several factors such as the size of rice fields, varieties, and rainfall. The greater the rice production in a region, the greater the potential of husk produced. Fauzi and Faradis (2016) analyzed factors affecting rice production in the five largest rice-producing districts in West Java. The analysis shows that land area has a positive effect on rice production where the more extensive a rice field, the greater the potential production yield per hectare. Meanwhile, labor and fertilizer use have a negative effect on rice production. However, studies in several other areas explain that labor and fertilizer use have a significant effect on rice production such as in Mahananto et al. (2009), Jumiati et al. (2016), and Hartati et al. (2018). This difference indicates that the standards of influential factors in rice production vary according to the expertise of researchers, climatic and weather conditions and the ability of farmers to implement good rice farming practices and management in accordance with standards.

4.2.1 Availability in Indramayu

The availability of rice husk is discussed based on milled dry grain (MDG) production data from BPS and daily rice production at the recorded rice mills. This is done to illustrate the estimated availability on average based on overall sample data and spatially based on the division of milling scale. The result of this estimation will be the mathematical calculation method of rice husk availability in a region. If the number of each mill based on its scale is known, the value of rice husk in the region can be estimated.

4.2.1.1 Availability Based on Dry Grain Rice Production Data Milled Grain (GKG)

Indramayu has been the largest rice production center in West Java and Indonesia for the past few years. Aside from being the national rice granary, an obvious implication of this fact is the potential rice husk waste that is available every year. Figure 9 shows the development of the theoretical amount of rice husk in Indramayu Regency over the last five years. The increase in rice husk potential has increased from 2018 to 2019 and from 2021 to 2022, while the decrease in potential occurred from 2019 to 2021. Anomalous conditions occurred in the decline in potential in 2020 to 2021 where this condition was thought to be influenced by two things, namely the lack of data or considerable milling activity from grain milled in Indramayu to outside the area. This condition returns to normal in the potential of 2022 which has a potential value of around 272,106 tons per year.

This potential is supported by good rice farming practices in terms of irrigation, fertilization, and management of farmers in Indramayu. According to KEMENTAN (2020), Indramayu is the best rice farming pilot location in Indonesia where in its implementation farmers can optimize supporting systems such as irrigation systems, superior seed varieties, adequate fertilizer, and utilization of tools and machinery facilities and capital or people's business credit funds (KUR).

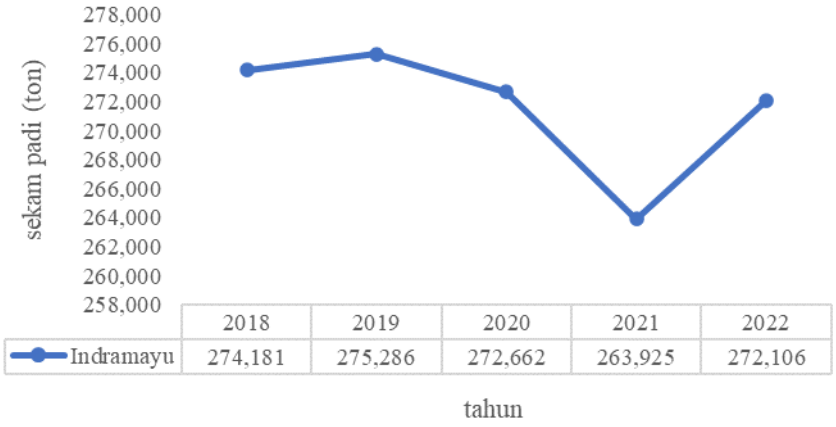


Figure 9 Rice husk potential in Indramayu Regency over the last five years

4.2.1.2 Availability Based on Overall Sample Data

The calculation of the quantity of husk was done using the rice mill location in Indramayu, which is where the rice husk supply originates. Another consideration is that the calculation of the husk fraction based on the GKG rice production from the existing rice field area is considered inadequate. This is because at each rice mill it was found that the rice milled was not only from Indramayu, so the amount of husk calculated from the rice area alone could not reflect the potential of rice husk in the whole region. Figure 14 shows the location map of the 95 sample data obtained from the field survey. The map was created with basic data in the form of coordinates of each rice mill location and a map of sub-district administrative boundaries in Indramayu District. Appendix 6 shows the collected sample data and a description of the daily rice production at each scale, which is the basis for calculating the daily husk potential.

The average rice production of rice mills in Indramayu is 5.72 tons/day. This value can generate a potential rice husk in Indramayu of 2,894 tons/day or 601,669 tons/year (Appendix 7). This potential exceeds the calculation of potential based on rice production data in Indramayu, which is 272,106 tons/year. This is because the source of paddy milled at the mill is not only from Indramayu, but also from other areas. Based on survey data, it is known that medium and large-scale millers

purchase grain from most cities or districts in Central Java and West Java provinces and a small portion in East Java and Banten provinces to support the daily production schedule in each week. Based on this finding, the calculation of rice husk availability in previous studies should be based on the husk yield at each rice mill so that the estimated value is close to the real availability in a region, not only based on statistical data on annual milled dry grain production multiplied by the husk fraction.

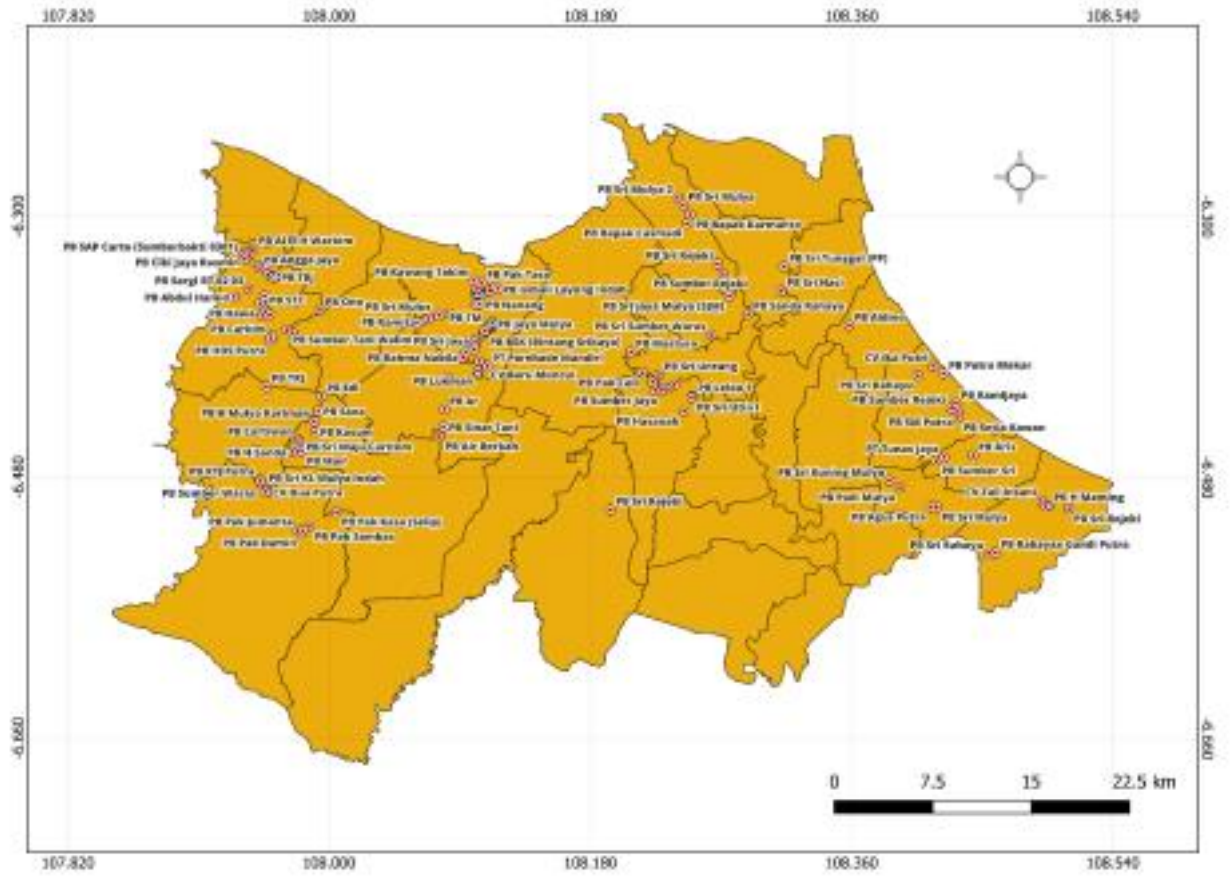


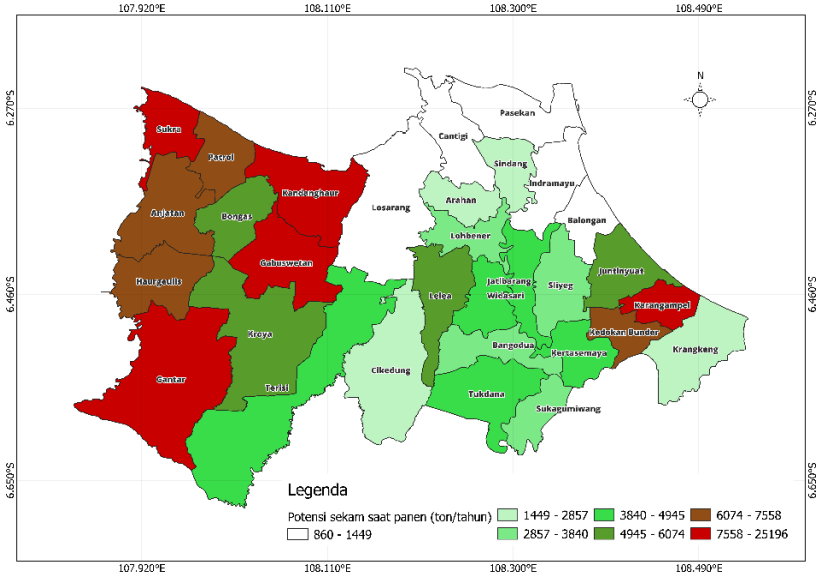
Figure 10 Map of 161 rice mill locations in Indramayu

4.2.1.3 Availability Based on Production Scale Division

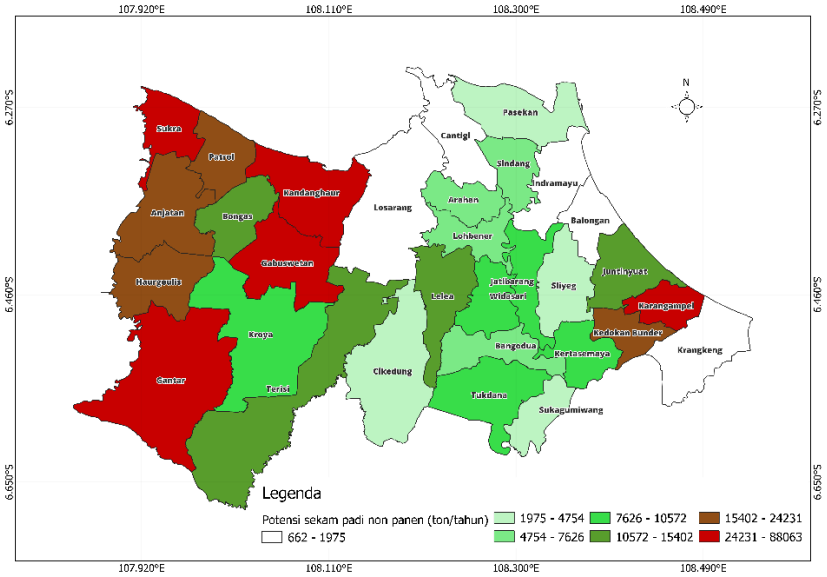
Based on the sample data collected, the total number of small-scale, medium-scale, and large-scale rice mills is 79, 12, and 4, respectively, according to the weighting calculation. The average daily rice production capacity at each scale is 2.79 tons/day, 15.5 tons/day, and 34.4 tons/day (Appendix 7). These values

indicate the availability of rice husk during harvest and non-harvest periods of 165,075 tons and 423,786 tons, respectively, with a total annual availability of 588,861 tons/year. The approach of calculating the availability of rice husk with this model can be used as an estimation value of the potential of rice husk in an area if it is known how many rice mills each scale.

The spatial distribution of rice husk is shown in Figure 15 where the availability of rice husk is presented in harvest and non-harvest periods. Tabular data on the husk potential of each sub-district can be seen in Appendix 8. The availability of rice husk is highest in Kandanghaur sub-district. Besides being influenced by the large number of mills, it is also influenced by the rice harvest area in the surrounding sub-districts but the number of rice mills is small. In Appendix 1 and Appendix 7, it can be seen that Losarang sub-district only has 20 rice mills and is dominated by small-scale mills, but Losarang's harvest area of 11,000 ha is larger than Kandanghaur's which is only 10,776 ha. In addition, farmers' preference for rice quality is a further factor in choosing medium-scale and large-scale mills over small-scale. According to Ulfa et al. (2014), many farmers began to choose to grind rice in medium and large-scale mills due to the premium rice yield. This is also the basis that many farmers and collectors prefer to grind their grain in medium and large-scale mills, including in Kandanghaur sub-district.



(a)



(b)

Figure 11 Availability of rice husk during harvest season (a) and during non-harvest season (b)

Figure 11 shows the distribution map of rice husk availability in tons/year in each sub-district. The highest availability of rice husk is found in Kandanghaur sub-district both during harvest and non-harvest periods, amounting to 25,196.17 and 88,063.13 tons/year, respectively. The high husk potential is influenced by the distribution of rice mills which are dominated by medium and large mills. In addition, the high chaff potential is also influenced by the large rice harvest areas in the surrounding subdistricts but the small number of rice mills. For example, in Appendix 1 and Appendix 4 it can be seen that Losarang sub-district only has 20 rice mills and is dominated by small-scale mills but Losarang's harvest area of 11,000 ha is larger than Kandanghaur at 10,776 ha. In addition, farmers' preference for rice quality is a further factor in choosing medium-scale and large-scale mills over small-scale. According to Ma'arif (2016), many farmers began to choose to grind rice in medium and large-scale mills due to the better quality of the rice. This is also the basis that many farmers and collectors prefer to grind their grain in medium and

large-scale mills, including in Kandanghaur sub-district. Meanwhile, the least amount of potential husk is found in Cantigi sub-district both during harvest and non-harvest periods, which is 860.13 and 661.64 tons/year respectively. This is due to the distribution of rice mills that are dominated by small-scale mills in addition to consumer preferences to grind in medium and large-scale mills. According to Alfi (2017), small rice mills operate with limited milling capabilities and old machinery, which causes the quality of the rice produced to be low.

4.3 Rice Husk Use Competition

The calculation of rice husk utilization aims to determine the amount of reduction in the availability of husk as biomass cofiring material. The use of rice husk in Indramayu is distributed into eight uses based on interviews with rice mill managers. Figure 12 shows the distribution of rice husk use, with the most husks used as fuel for the brick and tile industry and the least used as home fuel. The figure illustrates that in general, the use of rice husk is as fuel (brick, tile, and cement industry), planting media, and domestic use (road, cage, and home fuel). According to Barry et al. (2022), the sustainability potential of a biomass waste as an energy source is influenced by the density and competition of its use in an area.

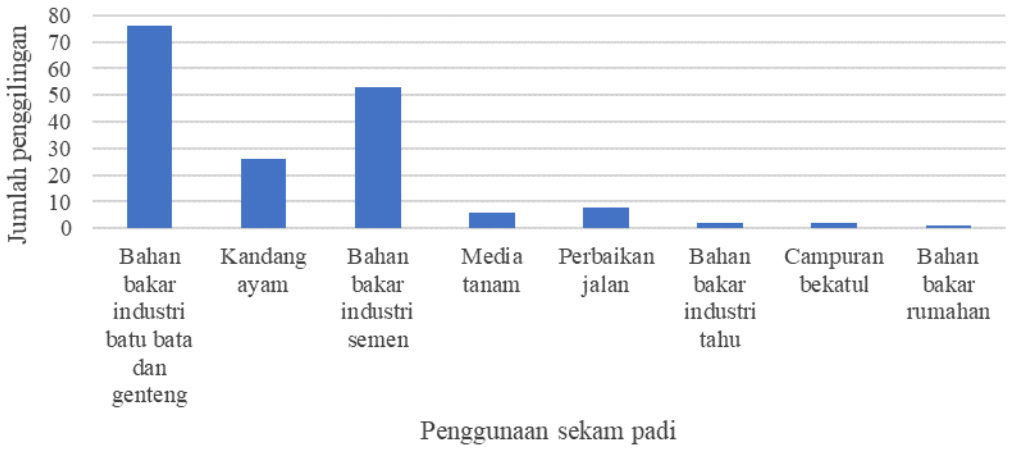


Figure 12 Distribution of rice husk use in Indramayu

The competition for the use of chaff in an area aims to determine the recovery fraction (a) as a multiplier of chaff availability in the previous estimation of potential. The recovery fraction in this study is divided based on the fraction during harvest and non-harvest periods. Small, medium, and large-scale rice mills have recovery fractions of 13.23%, 17.50%, and 23.33% in the harvest season and 3.90%, 10%, and 15% in the non-harvest season. According to Kemausuor et al. (2014), the recovery fraction is divided into three, namely a low level of 10%, a medium level of 25%, and a high level of 40%. Therefore, the recovery fraction of rice husk in this study is classified as very low, low, and medium where the lowest fraction is found in small-scale rice mills during the non-harvest season and the highest in large-scale rice mills during the harvest season. Most of the rice mills still have stockpiled husks that need to be transported especially during the harvest season or when there are big events such as celebrations. However, this unutilized potential can be allocated to sectors that still require biomass supply such as biomass cofiring feedstock in power plants.

4.4 Mobilizable Availability of Rice Husk

The recovery fraction obtained from the husk use competition data was used as a multiplier for the previous husk availability to obtain the mobilizable rice husk value. Appendix 9 shows the calculation of potential biomass that can be mobilized both during harvest and non-harvest periods in each sub-district in Indramayu. Spatially, it can be seen that the availability can be mobilized in Figure 13 where the most potential rice husk is found in the Kandanghaur sub-district with an availability of 16,929.48 tons/year. Meanwhile, the least availability is in Cantigi sub-district with a total husk of 173.34 tons/year. In addition, sub-districts with little rice husk potential (white and light green colors) are likely to grind rice in sub-districts with greater husk potential. Therefore, sub-districts such as Losarang, Cantigi, Indramayu, Balongan, and Krangkeng are suspected to mill rice in other sub-districts such as Kedokan Bunder and Karangampel and other sub-districts with greater husk potential.

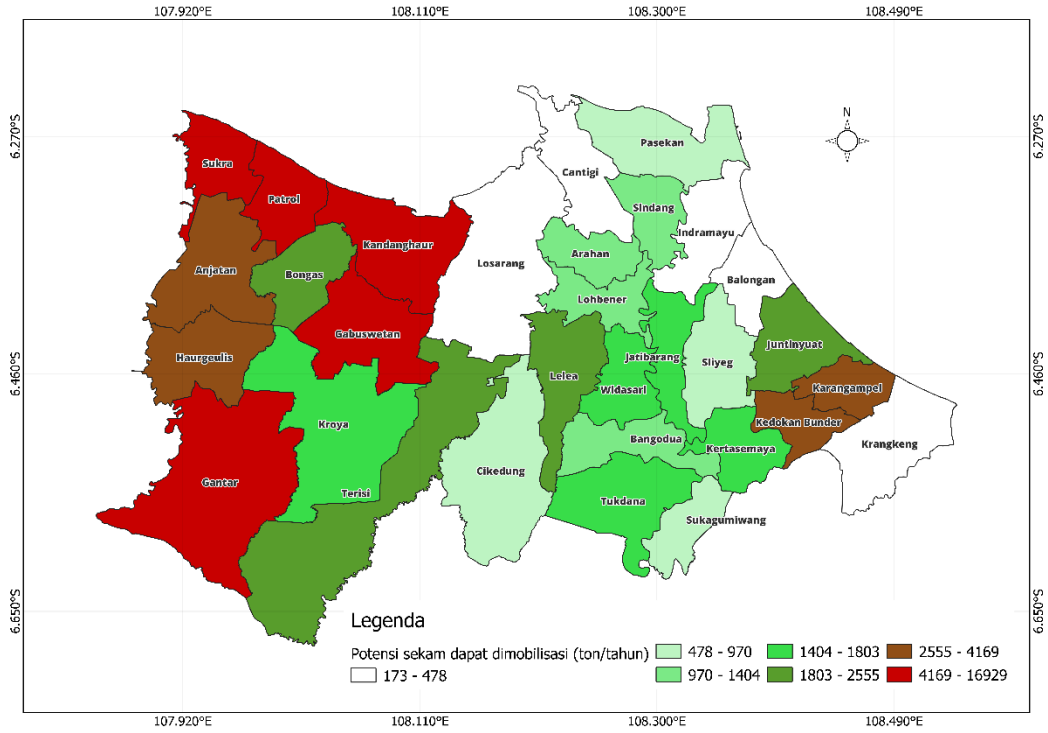


Figure 13 Availability of chaff can be mobilized in each sub-district

Based on Figure 13, the potential of rice husk can be obtained in large quantities in the western Indramayu region with several potential sub-districts including Kandanghaur, Sukra, Gabuswetan, Gantar, Patrol, Anjatan, and Haurgeulis sub-districts and the eastern Indramayu region including Karangampel, Kedokan Bunder, and Juntinyuat sub-districts. These sub-districts can be used as a location for the supply of rice husk biomass as a cofiring material for the Indramayu PLTU. The total availability of real rice husk is 79,761.95 tons/year. Biomass supply from rice husk waste is considered more economical and reduces the potential for deforestation and reduction of forest biodiversity due to the utilization of energy plantation forests (HTI) as cofiring feedstock for bioenergy production from wood. According to Muamar (2022), the use of wood pellets supplied under the HTE scheme would be highly risky in terms of supply chain processes and potential deforestation associated with increased greenhouse gas emissions. In energy conversion, four components need to be considered in its implementation, namely, conversion technology, production costs, availability of raw materials, and impact

on the environment. Information on the availability of rice husk can be used as an alternative supply of cofiring biomass. However, this potential can be increased by regulations on the use of husk for cofiring policies that can be supplied from rice mills. In addition to providing sustainability in the supply chain, the policy can also provide added value to rice husk.

V. Conclusion and Recommendation

5.1 Conclusion

The calculation of rice husk availability in an area can be known through data and information about rice mills as husk supply locations which include the number and scale of mills, operating hours and days, and daily rice production during harvest and non-harvest periods. This study collected a total of 161 rice mills with a distribution of small, medium, and large operating in 4, 5, and 6 days, respectively. Daily rice production at each scale has a husk potential of 0.87 tons/day, 4.83 tons/day, and 10.74 tons/day. The availability of rice husk in Indramayu was identified as 272,106 tons/year based on national production data. Spatial availability based on surveys and interviews is 601,669 tons/year while based on rice milling scale distribution is 588,861 tons/year. The competition of husk use in Indramayu is divided into eight use distributions with the most utilized for fuel in the roof tile, brick, and cement industries. The fraction of recovery at the small, medium, and large rice milling scale obtained from the competition of rice husk use in Indramayu is 13.23%, 17.50%, and 23.33% in the harvest season and 3.90%, 10%, and 15% in the non-harvest season respectively. Therefore, the real availability of rice husk in Indramayu is 79,761.95 tons/year which can be used as a biomass cofiring feedstock at the Indramayu PLTU. However, this value is considered quite low compared to the overall biomass demand where for national needs, this value will contribute 0.78% and locally for PLTU Indramayu, this value is estimated to contribute 31.90% of biomass supply. Policies related to the use of rice husk and its utilization are needed to increase supply while providing added value in the rice mill supply chain which is expected to benefit related parties, especially rice mill managers and surrounding communities.

5.2 Recommendation

This study suggests several things that can be done as further research including but not limited to:

1. Making a Web GIS application as an alternative to wider data access, including the community.

2. Collection of comprehensive rice mill data to obtain a more accurate mathematical model value for estimating the availability of husk

3. Policy analysis related to the management of small, medium, and large-scale mills that are integrated with government control and monitoring of their capacity capabilities in an area either village, sub-district, or district.

Acknowledgement

The research team would like to express our sincere gratitude to The Osaka Gas Foundation of International Cultural Exchange (OGFICE) for their generous support through the Research Grant FY 2022/2023. This funding has played a pivotal role in facilitating and advancing our research endeavors. The financial assistance provided by OGFICE through PPLH IPB University has not only allowed us to pursue in-depth investigations within our field but has also enabled the exploration of new dimensions in my work.

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RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	**:**	Process Intensification for Hydrogen Production from Sago Waste in Microbial Electrolysis Cell
	Ketua Penyelidik ***Project Leader***	**:**	Dr Hafizah binti Abdul Halim Yun
	Fakulti/Institut ***Faculty/Institute***	**:**	Faculty of Engineering
	Ahli Kumpulan Penyelidik ***Research Team Members***	**:**	Dr Mohd Farid bin Atan Ts. Dr Josephine Lai Chang Hui Ts. Sherena binti Sar-ee
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	**:**	January 2023
	Tempoh Projek ***Project Duration***	**:**	1 year 3 months
	Peruntukan Yg. Diluluskan ***Budget Approved***	**:**	RM 10,000.00
	Perbelanjaan Terkini ***Expenditure To-Date***	**:**	RM 1,764.68
C.	**Pencapaian Keseluruhan** ***Overall Achievement*** Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki.. *Describe the achievements in relation to the original objectives, hypothesis and research problems.*		

Since there is none of the literature has demonstrated the application of the artificial intelligence algorithm optimization to improve the predictability of the mathematical model for the study of simplified biofilm bacteria growth with a guarantee of real data from the experiment runs of fermentative biohydrogen via the MEC reactor, this research has been focusing on the development of mathematical of MEC for the hydrogen production from sago waste conversion that shows correlation with the experimental conditions, especially for the substrate concentration and the production rate.

Therefore, the overall achievements based on the objectives are listed as below,

1. To formulate the best approach to intensify hydrogen production.
Nonlinear convex optimization of the input values of the parameter associated with the stoichiometric reaction and kinetics and bio-electrochemical balance improved the validity of the results of the mathematical model approximating the experimental data of the sago effluent-fed MEC over 16 retention days for the substrate concentration profile and the hydrogen production rate profile. The ANN also proved that the model is able to predict the experimental hydrogen production rate based on the input of the pH of the catholyte at constant applied potential and constant current density.

2. To formulate and analyze the correlations between the input and output data
The study shows that bacterial growth (input data) at the biofilm level is responsible for dynamic hydrogen production (output data) in the MEC, emphasising the non-linearity associated with microbial reaction and kinetics. The concentration profile of the carbon sources shows that the substrate decreases while the acetate increases, which is due to fermentative metabolisation.

3. To determine the MEC performance through sensitivity analysis
The sensitivity test of the model shows that the hydrogen production rate increases rapidly when the initial concentration of the substrate in the influent decreases and simultaneously contributes to the fluctuation effect of the non-linear curve. The hydrogen production rate increases up to the maximum steady state of 0.033 $L \cdot day^{-1}$, while the decrease in substrate concentration reaches its steady state at a minimum of 476 $mg \cdot L^{-1}$.

D. Pencapaian Utama
Key Findings

The ANN has proved that the model is able to predict the experimental hydrogen production rate based on the input of the pH of the catholyte at constant applied potential and constant current density. The optimal input values for the operating conditions of applied potential, anode surface area, anodic chamber volume, and initial substrate concentration lead to the maximum percentages of COD removed efficiency, Coulombic efficiency, and energy efficiency of the model MEC, which indirectly improved the profile of hydrogen production rate and substrate concentration over time.
Moreover, the model shows that the sensitivity of the hydrogen production rate increases rapidly with the decrease of the initial substrate concentration in the influent, resulting in a fluctuation of the non-linear curve. The analysis also reveals that the hydrogen production rate reached the maximum steady state of 33.0 $mL \cdot day^{-1}$ at the optimum initial COD of influent wastewater of 476 $mg \cdot L^{-1}$

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	-
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	-
	Tesis pelajar PhD *Student's PhD thesis*	-
	Kertas persidangan tempatan *Local conference papers*	X
	Kertas persidangan antarabangsa *International conference papers*	-
	Makalah dalam jurnal tempatan *Local journal papers*	X
	Makalah dalam jurnal antarabangsa *International journal papers*	-
	Monograf atau buku *Book/monograph*	-

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

A paperwork has been submitted to The 15th International UNIMAS Engineering Conference 2024 (EnCon2024) where it has been accepted for the conference. The researchers attended the conference and presented the paper on 14 February 2024. However, it takes a while for the presented paper to publish in one of the selected Journal EnCon2024 (refer to list of journals EnCon2024 and first page of the paper),

Moreover, a manuscript has been submitted and accepted to be published in ASEAN Engineering Journal (refer to the acceptance email). However, the manuscript is in queue and takes time to be published under this special edition issue of this journal.

Thus, the details of the publications are to be confirmed once they have been published.

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
√	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
√	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case stud*y atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The ANN has proved that the model is able to predict the experimental hydrogen production rate based on the input of the pH of the catholyte at constant applied potential and constant current density. The optimal input values for the operating conditions of applied potential, anode surface area, anodic chamber volume, and initial substrate concentration lead to the maximum percentages of COD removed efficiency, Coulombic efficiency, and energy efficiency of the model MEC, which indirectly improved the profile of hydrogen production rate and substrate concentration over time.
The model also shows that the sensitivity of the hydrogen production rate increases rapidly with

the decrease of the initial substrate concentration in the influent, resulting in a fluctuation of the non-linear curve. The analysis also reveals that the hydrogen production rate reached the maximum steady state of 33.0 $mL \cdot day^{-1}$ at the optimum initial COD of influent wastewater of 476 $mg \cdot L^{-1}$

Moreover, the modelling study also has the potential for future extension by implementing a novel framework as a strategy to address the dynamic behaviour of hydrogen production rate in the MEC over multiple retention days.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:

- Borang ini dalam kedua-dua bentuk bercetak dan elektronik

Researchers are required to submit to the Research Centre:

- *This form in both hard- and soft-copies*

……. **……31 March 2024……**

Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	**:**	Mixed matrix PVDF membrane composed of bamboo nanocellulose for methylene blue dye removal via adsorption: an adsorption model study
	Ketua Penyelidik ***Project Leader***	**:**	Dr Khairul Anwar Mohamad Said
	Fakulti/Institut ***Faculty/Institute***	**:**	Faculty of Engineering
	Ahli Kumpulan Penyelidik ***Research Team Members***	**:**	1. AP Dr Md Rezaur Rahman 2. Mohamed Afizal Mohamed Amin
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	**:**	1 January 2023
	Tempoh Projek ***Project Duration***	**:**	1 year
	Peruntukan Yg. Diluluskan ***Budget Approved***	**:**	RM 10,000
	Perbelanjaan Terkini ***Expenditure To-Date***	**:**	RM 3,061

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

1. To investigate the effect of bamboo nanocellulose content to the membrane physicochemical properties and water flux performance

For the first objective, we found that the PVDF membrane consists of nanocellulose have high water flux up to 800-1000 L/m^2.h specifically for bamboo nanocellulose PVDF membrane. In comparison with pristine PVDF membrane, the recorded flux is around 300-450 L/m^2.h.

2. To elucidate the relationship of bamboo nanocellulose dosage to the removal of methylene blue

For the second objective, we have fabricated the membrane with different dosage of nanocellulose (1, 2 and 3wt%). We have tested the membrane with methylene blue dye initial concentration of 30 ppm. The result indicated PVDF membrane with 3wt% of nanocellulose able to reject ~90% of dye while pristine PVDF (without nanocellulose) can only remove 65% of methylene blue. The result indicate that the incorporation of nanocellulose in membrane will improve its ability to treat dye-rich water.

D. Pencapaian Utama
Key Findings

The inclusion of bamboo-derived nano cellulose in PVDF ultrafiltration membrane has improved its rejection up to ~90% with an average flux of ~800 L/m^2.h. However, we have not studied the resilience of this membrane for the long-term application of dye removal.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
	Kertas persidangan tempatan *Local conference papers*	
	Kertas persidangan antarabangsa *International conference papers*	x
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	x
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

n/a

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

The international journal paper, one manuscript is currently under review at Water, Air, & Soil Pollution (IF: 1.9), Springer since August 2023.

International conference paper, we have successfully submitted a manuscript to ENCON 2024 and will be presented on 14-15 February 2024.

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
x	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
x	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
x	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case stud*y atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

n/a

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

Clean water is predicted to become one of the most precious commodities on Earth toward the end of this century. Already, now, the majority of people living on the Earth do not have regular access to clean drinking water, despite access to clean drinking water being one of the most important human rights. The World Economic Forum rates the water crisis as the number one global risk in terms of societal risks; already today about 1 billion people do not have access to safe drinking water and about 800 000 people are killed every year as a result of consuming contaminated drinking water, inadequate handwashing facilities and inappropriate sanitation service. Methylene blue (MB) is one of the most commonly used substances for dyeing cotton, wool and silk. Various methods including micelle-enhanced ultrafiltration, oxidation processes, electrochemical degradation, ozone-based processes, photocatalytic degradation, electrocoagulation, nanofiltration, various types of activated carbon, biological treatments, and nanomaterials have been used to remove dyes from water. Due to the high cost and production of large quantities of sludge, the chemical process is unsuitable for dye removal. Bamboo is a cheap, renewable, and abundant lignocellulosic- based biomass resource in Malaysia. It has various applications, such as food sources, building materials, and other types of versatile raw biomass. The lignocellulose-based adsorbents are well known in wastewater treatment, for example, biochar, cellulose, and lignin-derived adsorbents. These bamboo-derived adsorbents have highly efficient environmental, and economic values. However, it is difficult to separate the bamboo-derived adsorbents from wastewater due to their small size and shape. One of the practical approaches to solve this issue is to embed bamboo fibre sources into a polymer matrix. The polymer matrix could allow the adsorbents to interact freely with cationic pollutants, and it can be separated from water easily. The findings show that the PVDF membrane consists of nanocellulose have a high water flux of up to 800-1000 L/m2.h specifically for bamboo nanocellulose PVDF membrane. In comparison with pristine PVDF membrane, the recorded flux is around 300-450 L/m^2.h. PVDF membrane with 3wt% of nanocellulose was able to reject ~90% of dye while pristine PVDF (without nanocellulose) can only remove 65% of methylene blue. The result indicates that the incorporation of nanocellulose in the membrane will improve its ability to treat dye-rich water.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
- Borang ini dalam kedua-dua bentuk bercetak dan elektronik

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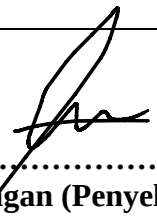

……. **……31/01/2024……**

Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	:	Incorporation of Cloisite 15A in the Polysulfone Matrix Membrane via Phase Inversion Method for Humic Acid Removal
	Ketua Penyelidik ***Project Leader***	:	Mohamed Afizal Bin Mohamed Amin
	Fakulti/Institut ***Faculty/Institute***	:	Faculty of Engineering, UNIMAS
	Ahli Kumpulan Penyelidik ***Research Team Members***	:	1. Dr Khairul Anwar bin Mohamad Said 2. Profesor Madya Dr. Md. Rezaur Rahman 3. Dr Dayang Norafizan binti Awang Chee
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	:	6 September 2022
	Tempoh Projek ***Project Duration***	:	1 tahun
	Peruntukan Yg. Diluluskan ***Budget Approved***	:	RM 10,000
	Perbelanjaan Terkini ***Expenditure To-Date***	:	RM 8,517.74

C. Pencapaian Keseluruhan
Overall Achievement

Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

Polysulfone polymeric membrane was successfully modified with Cloisite15A via phase inversion method. As the loading of Cloisite15A in the water bath increases, the amount of this material embedded on the membrane surface was also increase when membrane morphology was analyze using SEM-EDX instrument. When the filtration process was conducted using synthetic

heavy metal wastewater, membrane modified with Cloisite15A shows higher lead removal. At long term water filtration process, the membrane had show good performance in maintaining higher water flux.

D. Pencapaian Utama
Key Findings

The incorporation of Cloisite15A nanoclay in polysulfone matrix have a significant impact on membrane water filtration performance through the phase inversion strategy. This method can be implemented using other types of nanoparticles as a nonofiller in producing ultrafiltration membrane.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
	Kertas persidangan tempatan *Local conference papers*	
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	X
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

Said, K.A.M., Amin, M.A.M., Luisa, J. *et al*. Impact of Montmorillonite Clay on Polysulfone Mixed Matrix Membrane for Heavy Metal Adsorption. *Water Air Soil Pollut* **234**, 275 (2023). https://doi.org/10.1007/s11270-023-06275-y

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
x	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
x	Sesuai untuk dijadikan bahan pengajaran/*case stud*y atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
x	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi

Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')

(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

Ultrafiltration has received much attention for use in drinking and wastewater treatment. However, flux reduction due to membrane fouling is a crucial problem for its effective application. Cloisite15A with interesting properties including nano-scale sizes, high specific surface areas, cost-effectiveness, high adsorption capacity, and high hydrophilicity has been widely applied in water purification since ancient times. The incorporation of this nanofiller in membrane matrix via phase inversion technique impart an excellent property on nanocomposite membrane such as high heavy metal removal with low fouling propensity and hence allowing high water permeability for long operation process.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:

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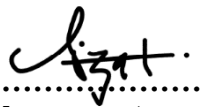

……. **……20/12/23……**

Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	:	Detection of Power Line Insulator Defects on Power Transmission Line Based on an Improved Faster Region-Convolutional Neural Network Algorithm
	Ketua Penyelidik ***Project Leader***	:	Annie Anak Joseph
	Fakulti/Institut ***Faculty/Institute***	:	Faculty of Engineering, UNIMAS
	Ahli Kumpulan Penyelidik ***Research Team Members***	:	1. Assoc. Prof. Ir Dr David Bong Boon Liang 2. Ts. Dr Kho Lee Chin 3. Ir Dr Ngu Sze Song 4. Dr Kuryati Kipli
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	:	6 September 2022
	Tempoh Projek ***Project Duration***	:	1 tahun
	Peruntukan Yg. Diluluskan ***Budget Approved***	:	RM 10,000
	Perbelanjaan Terkini ***Expenditure To-Date***	:	RM 9264.32

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

Initial investigation and background study had been done. This includes investigation

through the literature on the latest findings to develop the methods to detect the insulator and its defect. Besides, a series of theoretical studies and analyses were performed to understand techniques for insulators and their fault detection. The hybrid system based on You Only Look Once (YOLOv5) and Residual Neural Network (Resnet50) architectures is developed and some results are obtained. Index Conference paper is accepted for presentation and now waiting for the online publications. Overall the objectives are achieved.

D. Pencapaian Utama
Key Findings

The hybrid works of deep learning methods for the insulator fault can be further improved by locate the exact of the fault whenever the detection of the defect is identified.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
	Kertas persidangan tempatan *Local conference papers*	x
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

The paper is accepted for presentation at IEEE Conference on Energy Conversion 2023 On 23rd – 24th October 2023 at Imperial Hotel Kuching, Kuching, Sarawak, Malaysia and it is published online on 28th December 2023.

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
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	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
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	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
x	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case stud*y atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi

Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')

(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The research concentrates on designing and developing a method to detect the insulators' defects while maintaining a reasonably high speed. Hence, the project aims to propose an approach based on You Only Look Once (YOLOv5) and Residual Neural Network (Resnet50) to build an algorithm that detects and classify defect in insulators through images. The algorithm is developed using MATLAB through the deep Learning tool and trained using obtained datasets from online resources or datasets collected from the site. The project is proposed to ease the maintenance and inspection process of a transmission line by reducing potential hazards due to climbing towers and flying manned helicopter closed to the transmission line. The project is also proposed to enhance the automation inspection method of the transmission line system.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:

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……. **……20/12/23……**

Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	:	**The Behaviour of Dewatered Sewage Sludge and Fly Ash Mix as a Potential Recycling Product.**
	Ketua Penyelidik ***Project Leader***	:	NOR AZALINA ROSLI
	Fakulti/Institut ***Faculty/Institute***	:	Faculty of Engineering
	Ahli Kumpulan Penyelidik ***Research Team Members***	:	Leonard Lim Lik Pueh Jethro Henry Adam Inawati binti Othman Rosmina Ahmad Bustami
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	:	January 2023
	Tempoh Projek ***Project Duration***	:	1 year
	Peruntukan Yg. Diluluskan ***Budget Approved***	:	RM 8962
	Perbelanjaan Terkini ***Expenditure To-Date***	:	RM 8632.7

C. Pencapaian Keseluruhan
Overall Achievement

Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

As a whole, the fly ash from Mukah exhibits different properties compared to the fly ash obtained from Sejingkat. This disparity may stem from variations in plant operation and

treatment processes. When mixed with sewage sludge, Mukah fly ash demonstrated the potential to enhance the properties of the sewage sludge. However, the improved properteis are still not sufficient for the mixture to be used in certain applications. Therefore, for future work, the consideration of admixtures could be explored to further enhance the properties of the mixture.

D. Pencapaian Utama
Key Findings

1. Sewage sludge required modification to enhance the properties especially on the strength and plasticity
2. The fly ash from Sejingkat Power Plant does not have the potential to increase the strength of the sewage sludge. The strength of the fly ash itself is not high (less than 100 kPa). Therefore, when mixed with sewage sludge, the strength of the mixtures do not have any significant impact.
3. However, the fly ash from Mukah seems to show the potential as the strength of the fly ash itself is quite high (can reach up to more than 1000 kPa). The fly ash from Mukah is then mixed with the sewage sludge.
4. From the laboratory result, the mixture of sewage sludge and fly ash from Mukah also does not really giving significant impact toward the strength properties. For future works, admixtures might be required to enhance the properties of the mixture.
5. All the lab works are done.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
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	Kertas persidangan tempatan *Local conference papers*	
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	1
	Makalah dalam jurnal antarabangsa *International journal papers*	

	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

This paper will be submitted to Journal of Civil Engineering Science and Technology (JCEST), UNIMAS, Volum 15, Issue 2.

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

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√	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
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	Sesuai untuk dijadikan bahan pengajaran/*case stud*y atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

This study explores the potential of recycling sewage sludge and fly ash to enable the sustainable waste management. The chemical composition (Si, Al, Ca, Fe) in both sewage sludge and fly ash can complement each other, forming calcium silicate hydrate (CSH) gel. The interaction leads to the enhancement of the strength properties of the sewage sludge. With the desired strength and other properties, this mixture can be utilized for various application.

Catatan Penting/Important Notes

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……. **……9/1/24……**

Tandatangan (Penyelidik Utama) **Tarikh**
Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** ***Project Title***	**:**	INVESTIGATION OF MECHANICAL AND THERMAL PERFORMANCE OF LOCAL BAMBOOS IN SARAWAK AS CONSTRUCTION MATERIALS
	Ketua Penyelidik ***Project Leader***	**:**	MOHAMAD ISKANDAR BIN JOBLI
	Fakulti/Institut ***Faculty/Institute***	**:**	Faculty of Engineering, UNIMAS
	Ahli Kumpulan Penyelidik ***Research Team Members***	**:**	MAHSHURI YUSOF DIANA KERTINI MONIR MOHAMAD FAIZRIZWAN BIN MOHD SABRI
B.	**Tarikh Geran Diluluskan** ***Grant Approval Date***	**:**	6 September 2022
	Tempoh Projek ***Project Duration***	**:**	1 Tahun 3 Bulan
	Peruntukan Yg. Diluluskan ***Budget Approved***	**:**	RM 10 000.00
	Perbelanjaan Terkini ***Expenditure To-Date***	**:**	RM 7390.74

C. Pencapaian Keseluruhan
Overall Achievement

Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

In this research, four different local bamboo species were used to produce bamboo panels using specific lamination technique. The results were amazing that the mechanical

strengths of the bamboo panels are comparable to local wood species. At the same time, the thermal properties were also consistent to woody construction materials. In other words, the bamboo panels provide a promising future as substitutes for woody materials which is getting scarce. In summary, the aim and objectives of the research have been successfully achieved. Manuscript of research findings has been submitted to UNIMAS Engineering Conference 2024

D. Pencapaian Utama
Key Findings

Laminated bamboo panels from 4 wild Bamboo species in Sarawak have been fabricated, tested and analyzed. Betong Bamboo has the highest Mechanical Strength which is comparable to local wood Merpauh. For thermal properties, the bamboos possess similar traits to common wood in construction industry.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
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X	Kertas persidangan tempatan *Local conference papers*	1
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

F. Pengecaman Output
Output Identification

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	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
X	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
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Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The use of bamboo as an alternative construction material can be practically observed as part of the findings in this study. Sarawak has the potential to lead this industry as the number of unexploited bamboos in Sarawak forest are numerous. The utilisation of bamboo as construction materials is still low even at this very moment due to the lack of information found on its Mechanical and Thermal Properties. Furthermore, it was reported that bamboo varies significantly in terms of physical and mechanical performance with different species, location, age, climate and height. Thus, the findings from this study will serve as the foundation to lead this initiative for green and sustainable construction materials.

In this research, four different local bamboo species were used to produce bamboo panels using specific lamination technique. The results were amazing that the mechanical strengths of the bamboo panels are comparable to local wood species. At the same time, the thermal properties were also consistent to woody construction materials. Thus, it can be concluded that Sarawak bamboo has the potential to replace current woody construction materials for the sustainability in Construction Industry.

Catatan Penting/Important Notes

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Researchers are required to submit to the Research Centre:
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29 March 2024

……. …….

Tandatangan (Penyelidik Utama)
Signature (Principal Researcher)

Tarikh
Date