Research Paper

IRA Journal of Engineering Science and Technology

Available online https://e-journals.irapublishing.com/index.php/IRAJEST

Vol.1, No.1, 2025, pp. 8-15, e-ISSN: XXXX- XXXX

https://doi.org/10.56862/irajest.v1i1.132

Utilization of Archimedes' Water Turbine for Mobile Phone Charging in Rice Fields

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Received: **2025-05-05** Revised: **2025-06-02** Accepted: **2025-06-23** Published: **2025-06-30**

Abstract

This study evaluated the performance of small-scale screw Archimedes turbines for mobile phone charging in low-head rice fields. Field tests were carried out at ±0.60 m head with an average discharge of 0.0369831 m^3/s. The parameters measured include discharge, torque, revolution, turbine power, generator output power, and battery charge profile. Hydraulic power was recorded at 216.808 W, turbine power was 17.9785 W at 931 rpm, and peak generator power was 27.84 W. The system charged the battery from 0% to 100% in 180 minutes with a constant current phase at the beginning and a near-full current drop. The overall efficiency of hydraulic power reaches 12.85%. The results demonstrate the feasibility of utilizing off-grid microhydro systems on agricultural land. Recommendations include optimization of blade geometry, tilt angle, transmission, and use of DC-DC CC–CV converters. Improved instrumentation and retest on discharge and head variations are recommended.

Keywords: Turbine Archimedes screw, Off-grid microhydro, Battery charging, Rice field irrigation.

1. Introduction

Electricity is a vital need of the community that cannot be separated from daily life [1-3]. Starting from its simplest function, namely lighting, to other functions as a means of obtaining entertainment and information, such as television, radio, mobile phone charger, and others. In this modern era, electricity is also used to replace fuel oil or gas used for cooking through the use of electric cooking tools, such as rice cookers and electric water cookers [4-7]. Likewise, in the current era of information and openness, mobile phones have also made their way into villages [8-11].

In the end, when the demand for electricity increases, while the government's ability to produce electricity is limited, there is an electricity crisis everywhere [12-14]. Thus, the distribution of electricity in Indonesia cannot be said to be successful, as Indonesia consists of approximately 17,500 islands, making transportation from one place to another still challenging to achieve [15-17]. This is further complicated by the topography, which is generally mountainous with slopes ranging from gentle to very steep; as a result, many remote villages have not yet received electricity, according to data from the State Electricity Company.

One of the sources of renewable energy is water (hydro) energy [18-20]. The use of water energy (hydro) is targeted to reach 4% of national energy use by 2025 [21-22]. To meet this target, it is necessary to increase the use of water resources (hydro) spread across all regions in

Indonesia as a source of renewable energy [23-25]. One of the categories of water resources, such as renewable energy (electrical energy), that is very promising is Micro Hydro Power Plants [26-28].

Therefore, this study will utilize the Archimedes screw turbine for mobile phone charging in rice fields, analyzing the effect of water discharge at 0.0369831 m^3/s. This will involve calculating the turbine's efficiency and the generator's power.

The flow discharge is measured by the closed channel method using a 200-liter drum. The equation calculates discharge:

$$Q = \frac{v}{t} \quad (1)$$

with V-rated water volume and t charging time. The effective head is about 0.6 m set from the channel geometry and turbine position.

Calculating the Head on an Archimedes Screw turbine with tilt angle:

$$b = \sqrt{c^2 - a^2} \quad (2)$$

To be able to calculate the power produced by the turbine or the power of the Hydrolis, one can refer to the equation.

$$PH = \rho \times g \times Q \times h \quad (3)$$

The shaft torque is obtained from the difference in the load mass and the lever radius:

$$T = (m_2 - m_1) \times g \times r \quad (4)$$

The calculation of turbine power is carried out in the following way:

$$P_t = (2 \,.\, \pi \,.\, n \,.\, T) / 60\% \quad (5)$$

Power generator using an equation that refers to the equation:

$$P_{out} = V \times I \quad (6)$$

$$\eta = \frac{P_H}{P_{out}} x100\% \quad (7)$$

2. Methods

The place where this research was carried out was the Pond Village. Percut Sei Tuan District, Deli Serdang Regency, North Sumatra. The tools and materials used in this study are: tachometer, AVO meter, stopwatch, watt meter, USB port, battery charger, battery, and for the material itself, an Archimedes screw turbine (Figure 2). The method used for this study is direct observation in the field to obtain results that align with the parameters.

Figure 1. Turbin Archimedes

The parameters in this study aim to calculate the turbine power at a discharge of 0.037 m^3/s, then calculate the generator power, turbine efficiency, and current strength in the charging system. This study utilizes the above parameters to determine the power produced by the turbine. It then calculates the power produced by the generator to determine the rotation and output power of the generator. Additionally, it calculates the efficiency created by the turbine and the current strength required for mobile phone charging.

Table 1. Heater dimensions and specifications

Description	Size (mm)
Turbine length	870.00
Upper shaft length	100.00
Lower shaft length	200.00
Turbine diameter	350.00
Shaft diameter	50.00
Outer diameter of the shaft tube	190.00
Inner diameter of the shaft tube	185.00
Blade spacing	290.00
Blade height	80.00

3. Results and Discussion

3.1. Results

Table 2 is a flow discharge measurement; the discharge is measured using a 200-liter drum. The charging time drops from 6.80 s to 4.30 s. Discharge increased from 0.0294117 m^3/s to 0.0465116 m^3/s. The average discharge value was reached at 0.0369831 m^3/s. The variation between measurements is still within a reasonable range. This data shows the flow is stable enough for testing.

Table 2. Flow-rate measurements

Trial	Volume, V (m^3)	Time, t (s)	Discharge, Q (m^3/s)	Equation Ref.
1	0.20	6.800	0.029	Eq. (1)
2	0.20	5.710	0.035	Eq. (1)
3	0.20	4.300	0.047	Eq. (1)
Average	0.20	5.600	0.037	Eq. (1)

Table 3. Summary of key calculations

Quantity	**Unit**	**Value**	**Equation Ref.**
Head, h	m	0.600	Eq. (2)
Hydraulic power, P_H	W	216.808	Eq. (3)
Torque (load method), T	N·m	0.262	Eq. (4)
Turbine speed, n	rpm	931.000	Input to Eq. (5)
Torque for T	N·m	0.185	Eq. (5)
Turbine power, P_t	W	17.979	Eq. (5)
Generator voltage, V	V	24.000	Input to Eq. (6)
Generator current, I	A	1.160	Input to Eq. (6)
Generator power, P_{out}	W	27.840	Eq. (6)
Efficiency, η	%	12.850	Eq. (7)

Table 3 is a summary of the main calculations. The effective head of the system is 0.60 m. The available hydraulic power is 216,808 W. The torque from the load method reaches 0.2619 N·m. The rated turbine speed is 931 rpm. The torque during the power test was 0.1845 N·m. The turbine power is recorded at 17.9785 W. The generator voltage is 24.00 V with a current of 1.16 A. The output power of the generator is 27.84 W. The efficiency against hydraulic power is 12.85%. The difference in power indicates mechanical and electrical losses in the prototype. The deviation of the instrument's readings can also affect the figure.

Table 3 presents a profile of mobile phone charging, showing that the battery level increased from 0% to 100% in 180 minutes. The load power decreases from 4.47 W to 1.43 W. The voltage fluctuates slightly in the range of 11.58–12.09 V. The current drops from 0.37 A to 0.12 A at the end of charging. The fastest level increase occurs until the 90th minute. After 120 minutes, the charging rate slows down to full. This data confirms the system is feasible for charging small devices.

Table 4. Mobile-phone charging profile (30-minute steps)

Time (min)	Voltage, V (V)	Current, I (A)	Power, P (W)	Battery Level (%)	Equation Ref.
0	12.09	0.37	4.47	0.00	Eq. (6)
30	11.99	0.37	4.43	13.00	Eq. (6)
60	11.89	0.37	4.39	49.00	Eq. (6)
90	11.86	0.37	4.36	76.00	Eq. (6)
120	11.58	0.37	4.28	84.00	Eq. (6)
150	11.85	0.26	3.08	92.00	Eq. (6)
180	11.97	0.12	1.43	100.00	Eq. (6)

3.2. Discussion

The discharge graph in Figure 2 shows a gradual increase from 0.0294117 m^3/s in experiment 1, to 0.0350262 m^3/s in experiment 2, and to 0.0465116 m^3/s in experiment 3. An average line of 0.0369831 m^3/s cuts through the bar between experiments 2 and 3, indicating that the test discharge is likely to be stable with an upward trend. Compared to the average, experiment 1 was about 20% lower, while experiment 3 was about 26% higher, so variation is still reasonable for field tests. The time graph in Figure 3 shows a downward trend from 6.80 s to 4.30 s, with the average line of 5.60 s being in the middle of the value distribution. The relationship between the two graphs is consistent because the discharge is inversely proportional to the charging time at a fixed volume. Hence, the increase in discharge explains the shortening of the time. The increase in discharge from experiments 1 to 3 was about 58%, followed by a decrease in time of about 37%, which confirms the influence of flow control and channel conditions. Minor differences between measurements are likely to come from local turbulence, operator response at stop-start, and measurement device resolution. In practical terms, valve stabilization, current damping, and increasing the number of repeats will reduce deviations as well as strengthen the basis for associating discharge with turbine performance and generator output.

Figure 4 shows the battery level rising steadily from 0% to 100% in 180 minutes. The fastest charging rate occurs within 30–90 minutes, with a rate of approximately 1.20%/minute in the 30–60 minute range and 0.90%/minute in the 60–90 minute range. After the 120th minute, the pace slows down by about 0.27%/minute until it is full. This pattern aligns with Figure 4, where the current remains at 0.37 A until the 120th minute, then drops to 0.26 A and 0.12 A. This means that the initial phase is dominated by constant current to charge quickly, then enters the voltage locking phase with a decreasing current. Figure 5 corroborates these findings because the power was relatively flat at 4.47–4.28 W until the 120th minute, then dropped sharply to 3.08 W and 1.43 W. Figure 6 shows the source voltage gradually decreasing from 12.09 V to a low of 11.58 V at the 120th minute, then recovering to 11.97 V when the current is tapering. The voltage sag at the beginning reflects the constant load of the charging process, while the recovery at the end occurs when the load decreases.

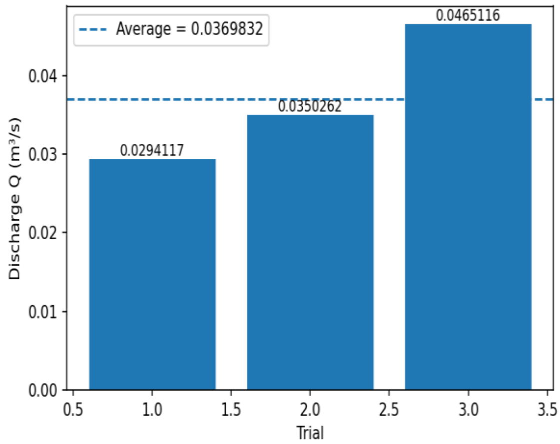

Figure 2. Discharge Q by trial

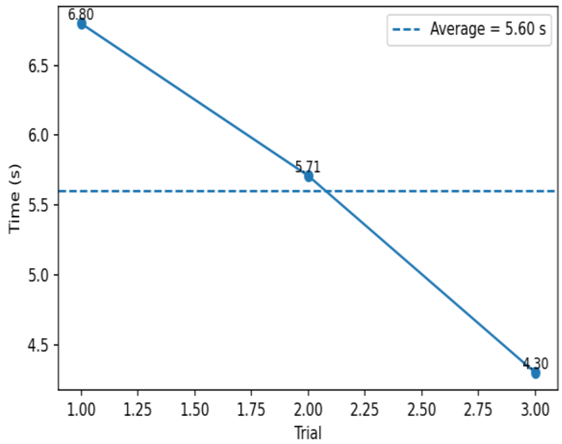

Figure 3. Fill time by trial

Figure 7 shows the charging current profile for 180 minutes. At 0–120 minutes, the current remains at 0.37 A, allowing for rapid charging in the initial phase. The transition point appeared in the 120th minute; the current drops to 0.26 A at the 150th minute (≈30% lower than the beginning) and then to 0.12 A at the 180th minute (≈68% lower). The four graphs form a consistent narrative: the system provides a stable supply for charging acceleration in the first half, then naturally reduces the current to ensure safe charging towards full capacity. Optimization can be focused on the rotation stabilizer and the current/voltage DC-DC regulator to achieve even power, minimize conversion losses, and reduce charging duration in subsequent tests.

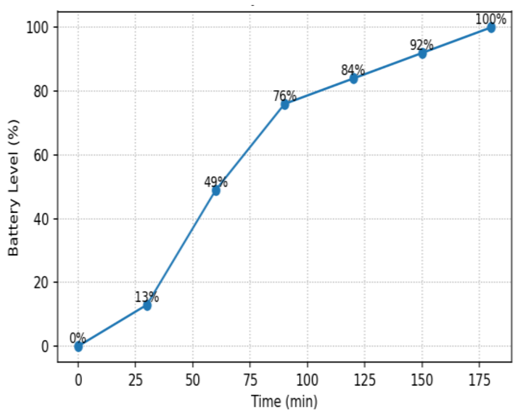

Figure 4. Battery level versus time

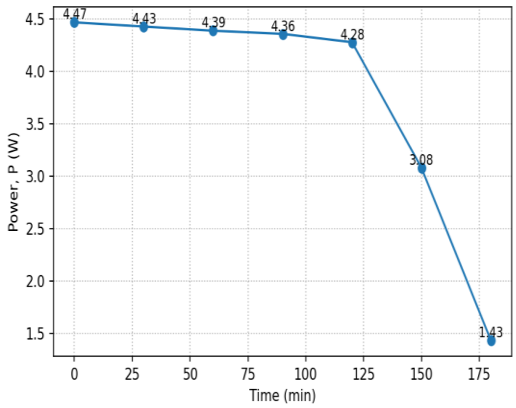

Figure 5. Power versus time

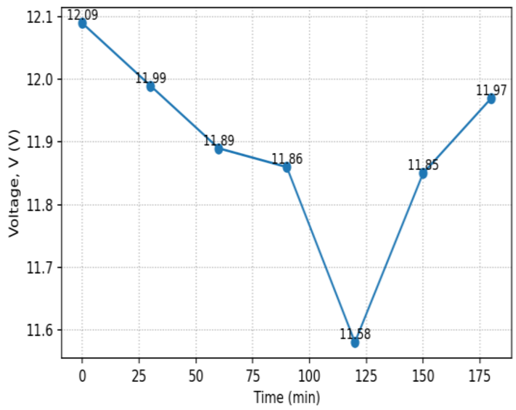

Figure 6. Voltage versus time

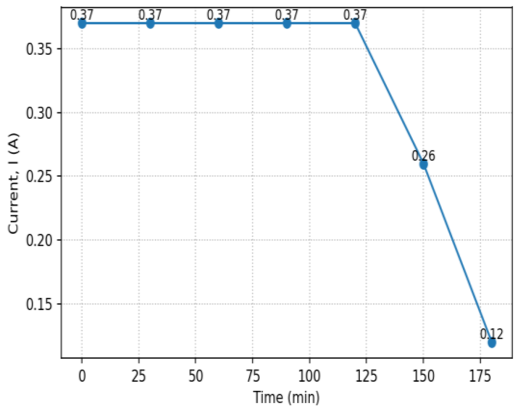

Figure 7. Current versus time

4. Conclusion

Research shows that the Archimedes turbine at a head of 0.60 m and an average discharge of 0.0369831 m^3/s is capable of supplying power for phone charging. The hydraulic power was recorded at 216.808 W, while the turbine power was 17.9785 W, and the electrical output was 27.84 W at the best test conditions. The overall efficiency of hydraulic power is valued at 12.85%, which reflects the mechanical and electrical losses of the prototype. The current and power graph shows the constant current phase until the 120th minute, after which the current decreases, and the voltage pattern recovers. The battery level increases from 0% to 100% in 180 minutes at a fast pace in the first half of the charge. These results confirm the feasibility of off-grid microhydro systems for small power needs in the area.

Optimization of screw geometry needs to be carried out through adjustment of pitch, height, and number of spoons, as well as gaps with the casing. An inclination angle of 30°–38° is worth testing for increased volumetric efficiency at local discharge. Mechanical losses can be reduced through shaft alignment, the use of closed bearings, good lubrication, and low-loss clutches. The transmission ratio and generator selection should be set so that the torque-rpm working point is in the peak efficiency region. Electrical chains are recommended to use a rectifier and DC-DC converter of type CC–CV to 5 V USB for stable initial current and controlled tapers. Rotational stability can be improved with a small flywheel, flow reducer, and particle filter on the inlet side. Instrumentation needs to be strengthened through the use of data loggers, uncertainty analysis, and repeated tests on discharge and head variations. Field safety must be maintained with overcurrent protection, short circuit protection, IP-certified covers, and orderly operating procedures.

Acknowledgments

The author expressed his gratitude to the Kolam Village Government and the irrigation management group in Percut Sei Tuan District for the location permit and field logistics support. Appreciation was expressed to the Mechanical Engineering Study Program, University of Medan Area, for access to test equipment and instrument calibration assistance. Thank you to the laboratory technicians and student assistants who helped with prototype assembly, data collection, and implementation of safety procedures. This research received facility support from the University of Medan Area and independent funding from the author. Awards were also given to colleagues for technical input during the manuscript drafting process. Any errors in analysis and interpretation remain the responsibility of the author.

References

[1] Z. Hu, X. Tan, and Z. Xu, "Analysis of Major Factors Which Affect Electricity Demands," in *An Exploration into China's Economic Development and Electricity Demand by the Year 2050*, Elsevier, 2014, pp. 101–116. doi: 10.1016/B978-0-12-420159-0.00004-7.

[2] S. P, S. S. R. J. S, and I. V, "Biomass Gasification using Coconut Shell for Small-Scale Electricity Generation," in *2022 Smart Technologies, Communication and Robotics (STCR)*, IEEE, Dec. 2022, pp. 1–5. doi: 10.1109/STCR55312.2022.10009137.

[3] S. F. Nisrina, M. A. Mudzakir, and B. Rahmat, "Utilization of Solar Panel Technology to Save Electricity Costs in Fish Farm Irrigation," *Journal of Computer Networks, Architecture and High Performance Computing*, vol. 6, no. 3, pp. 913–922, Jul. 2024, doi: 10.47709/cnahpc.v6i3.3969.

[4] V. Sivasamy, N. Yusoff, and A. Abd-Rahman, "Powering electric cars in Malaysia with green electricity produced from oil palm biomass," *IOP Conf Ser Mater Sci Eng*, vol. 736, no. 3, p. 032014, Jan. 2020, doi: 10.1088/1757-899X/736/3/032014.

[5] M. J. B. Kabeyi and O. A. Olanrewaju, “Sustainable Energy Transition for Renewable and Low Carbon Grid Electricity Generation and Supply,” *Front Energy Res*, vol. 9, Mar. 2022, doi: 10.3389/fenrg.2021.743114.

[6] S. Yang, A. Jahanger, and A. Awan, “Temperature variation and urban electricity consumption in China: Implications for demand management and planning,” *Util Policy*, vol. 90, p. 101782, Oct. 2024, doi: 10.1016/j.jup.2024.101782.

[7] M. Chairul Fahmi and M. Idris, “Studi Eksperimental Angka Setana Diproduksi dari Minyak Goreng Bekas,” *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, vol. 3, no. 1, pp. 101–107, Apr. 2024, doi: 10.56862/irajtma.v3i1.102.

[8] M. Farghali *et al.*, “Social, environmental, and economic consequences of integrating renewable energies in the electricity sector: a review,” *Environ Chem Lett*, vol. 21, no. 3, pp. 1381–1418, Jun. 2023, doi: 10.1007/s10311-023-01587-1.

[9] I. Wahyu Setya Andani, A. Sugiyono, K. Khotimah, and B. Desryanto Siregar, “Decarbonizing the electricity system in Sumatra region using nuclear and renewable energy based power generation,” *IOP Conf Ser Earth Environ Sci*, vol. 753, no. 1, p. 012011, May 2021, doi: 10.1088/1755-1315/753/1/012011.

[10] R. Wiranata and M. Idris, “Penyelidikan Eksperimental Alat Pengisi Daya Menggunakan Termoelektrik Dengan Pemanfaatan Panas Knalpot Sepeda Motor,” *Jurnal Ilmiah Teknik Mesin & Industri (JITMI)*, vol. 2, no. 1, pp. 21–30, Jun. 2023, doi: 10.31289/jitmi.v2i1.1950.

[11] M. Hussein and M. Idris, “Studi Eksperimental Titik Nyala dan Viskositas Biodiesel Diproduksi dari Minyak Goreng Bekas,” *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, vol. 3, no. 1, pp. 86–92, Apr. 2024, doi: 10.56862/irajtma.v3i1.101.

[12] C. Z. Yee *et al.*, “Developing a solar PV system for cost-effective electricity reduction in an aluminium extrusion plant,” *IOP Conf Ser Earth Environ Sci*, vol. 1372, no. 1, p. 012081, Jul. 2024, doi: 10.1088/1755-1315/1372/1/012081.

[13] S. Legino, R. Arianto, and N. Pasra, “The attainment of 100 percent electrification ratio in the archipelago of Indonesia by people way electricity initiative,” *J Phys Conf Ser*, vol. 1282, no. 1, p. 012057, Jul. 2019, doi: 10.1088/1742-6596/1282/1/012057.

[14] Muhammad Idris *et al.*, “The influence of catalyst on the characteristics of biodiesel from waste cooking oil,” *JTTM : Jurnal Terapan Teknik Mesin*, vol. 4, no. 2, pp. 254–262, Jul. 2023, doi: 10.37373/jttm.v4i2.676.

[15] M. Idris *et al.*, “Engine Performance Using Blended Fuels of Biodiesel and Eco Diesel,” *Energy Engineering*, vol. 120, no. 1, pp. 107–123, 2023, doi: 10.32604/ee.2023.019203.

[16] M. Idris, M. Mohd Zamberi, A. Fuad Abdul Rasid, Y. Zhang, E. P. Salim Siregar, and U. Novalia Harahap, “Sustainable Biodiesel Production with Heterogeneous Catalysts: Insights from a Systematic Literature Review,” *Journal of Advanced Research in Micro and Nano Engineering Journal homepage*, vol. 37, pp. 1–23, 2025, doi: 10.37934/armne.37.1.123.

[17] S. Saputra, M. Idris, M. Yusuf, and R. Siahaan, “Analisis Pengaruh Panas dan Beban terhadap Kerusakan Traveling Grate pada Boiler Di PLTU Tembilahan 2 × 7 MW Analysis of Heat and Load Effect on Traveling Grate Damage in Boilers at PLTU Tembilahan 2 × 7 MW,” pp. 2010–2019.

[18] I. Hermawan, M. Idris, I. Iswandi, and R. Syah, “Design and Comparative Analysis of Vortex and Whirlpool Type Turbines in Assessing the Performance of Micro Hydro Power Plant,” *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 119, no. 2, pp. 13–22, Jul. 2024, doi: 10.37934/arfmts.119.2.1322.

[19] I. Hermawan, M. Idris, A. P. Wibisono, and H. Satria, “Exergy Analysis of Coal-Based 2 X 7 MW Steam Power Plant,” *International Journal of Electrical, Energy and Power System Engineering*, vol. 6, no. 3, pp. 200–204, Oct. 2023, doi: 10.31258/ijeepse.6.3.200-204.

[20] Muhammad Idris, Tino Hermanto, Rahmad Syah, Muhammad Husein, and Sapriadi Sitinjak, “Pembuatan Biodiesel Dari Limbah Minyak Goreng: Studi Perbandingan Berbagai Waktu Reaksi,” 2024. [Online]. Available: http://ojs.polmed.ac.id/index.php/Sinergi/index

[21] M. Idris, A. Prasetyo Wibisono, I. Hermawan, and U. Novalia Harahap, “Analisis Pengaruh Ukuran Batubara Terhadap Performa PLTU dengan Jenis Boiler Tipe Chain Grate Analysis Coal Size Effect on Power Plant Performance with Chain Grate Type of Boiler,” *JMEMME*, vol. 6, no. 01, 2022, doi: 10.31289/jmemme.v6i1.5985.

[22] I. Hermawan, M. Idris, D. Darianto, and M. Y. R. Siahaan, “Kinerja Mesin Motor 4 Langkah dengan Bahan Bakar Campuran Bioetanol dan Pertamax,” *Journal Of Mechanical Engineering Manufactures Materials And Energy*, vol. 5, no. 2, pp. 202–210, Dec. 2021, doi: 10.31289/jmemme.v5i2.5787.

[23] M. Idris, T. Hermanto, R. Syah, M. Husein, and S. Sitinjak, “Pembuatan Biodiesel Dari Limbah Minyak Goreng: Studi Perbandingan Berbagai Waktu Reaksi,” *SINERGI POLMED: Jurnal Ilmiah Teknik Mesin*, vol. 5, no. 1, pp. 64–71, Mar. 2024, doi: 10.51510/sinergipolmed.v5i1.1537.

[24] M. Idris, I. Hermawan, I. Iswandi, and F. D. J. Waruwu, “Analisis PLTS Sebagai Sumber Daya Sistem Pakan Ikan Otomatis,” *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, vol. 1, no. 3, pp. 62–75, Jan. 2023, doi: 10.56862/irajtma.v1i3.35.

[25] M. Idris, A. F. Abdul Rasid, M. Mohd Zamberi, and Y. Zhang, “Biodiesel Production from Waste Cooking Oil: A Review of Prospects and Challenges,” *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 124, no. 1, pp. 28–52, Nov. 2024, doi: 10.37934/arfmts.124.1.2852.

[26] K. S. Sembiring, M. Idris, Y. M. Hasibuan, U. N. Harahap, and D. Darianto, “Studi Eksperimental Kalor Biodiesel dari Minyak Goreng Limbah,” *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, vol. 3, no. 3, pp. 95–102, Dec. 2024, doi: 10.56862/irajtma.v3i3.160.

[27] M. Syafrizal, Irwansyah, Siswo Pranoto, M. Idris, D. Darianto, and Indra Hermawan, “Design of Distillation Equipment for Extracting Atsiri Oils from Serai Wangi Leaves Using the Steam and Water Method,” *Journal Of Mechanical Engineering Manufactures Materials And Energy*, vol. 8, no. 2, pp. 140–146, Nov. 2024, doi: 10.31289/jmemme.v8i2.6402.

[28] Idris Muhammad, Abdul Rasid Ahmad Fuad, Mohd Zamberi Mahanum, and Zhang Yang, “Biodiesel Production from Waste Cooking Oil_ A Review of Prospects and Challenges,” vol. 124, no. 1, pp. 28–52, Dec. 2024, doi: https://doi.org/10.37934/arfmts.124.1.2852.