**International Journal Research in Engineering Science & Business Management (IJRESBM)**
*Volume 1 Issue 1 Nov-Dec 2025*
***ISSN: 3108-1878***
*www.ijresbm.com*

# The Key Performance Indicators For TPA Waste Processing Technology Into Alternative RDF (Refuse Derrived Fuels) Fuel

[1]Farid Mujayyin, [2]Dea Argita Gunarso

***ABSTRACT:*** *In line with the national energy needs, all districts or cities that have the potential to process waste into fuel must be supported by good preparation. The preparation must also be mapped out in the stup for an integrated waste disposal area that can be useful as a renewable energy source, for example a substitute for coal. This technology has the potential value of its use to produce more material to be used as a source of fuel for the purpose of the production process in several industries and also for the purposes of daily life. The technology for processing waste into RDF (Refuse Derived Fuels) is a technology that supports the exploration of potensial new materials, there are several stages of the technology, including sorting the types of waste, chopping waste become briquette molds. The purpose of this study is to determine the production and maintenance process for processing waste into RDF alternative fuel. Operational standards for processing waste into RDF require standard performance indicators using six sigma DMAIC including setting RDF production standards, measuring machine capabilities, determining the main causes of engine damage, determining improvements and increasing production rates, and controlling the production process. In this study, it can be identified the cause of low machines caused by constraints on the shredder machine which often turns off after repairs. Based on the KPI target that waste processing off after reapairs. Based on the KPI target that waste processing technology is assessed from a production capacity of 3 tons / day, RDF distribution to the factory 2 time / day, availability ratio of 85%, performance ratio 88%, Quality ratio 86%, number of mechanics 1 person, increased inspection 2 time/day, decreased downtime 2 time/month, number of periodic maintenance 3 times, number of equipment tools/spare parts 10 units, defective product 5 kg. After calculating the OEE (Overal Effectiveness Equipment) value, it can be determined and optimized. Based on the OEE value reaching 94%, it can be said that the production process of waste processing technology into RDF can improve and operate continuously.*

**Keywords***: performance, technology, RDF, maintenance*

## I. INTRODUCTION

Energy needs in Indonesia are recorded to increase every year with the increase in population and advances in technology and industry. But on the other hand, the available energy reserves in Indonesia will decrease over time. Therefore, to overcome the energy crisis, new alternative energy sources are needed which are cheaper, more abundant and can be renewed. Alternative energy that is currently being developed is alternative fuel RDF (refuse derived fuels). Fulfillment of energy needs needs to be reduced, given the dwindling availability of fossil fuels and the process of forming fossil fuels takes millions of years (Wahyu et. all. 2022). More than that, the process of burning fossil fuels releases carbon that was previously stored in the bowels of the earth, resulting in an accumulation of carbon in the atmosphere that is getting higher. One of the renewable energies that can be obtained effectively is an alternative fuel from the remaining piles of garbage used as fuel for the supply of industrial combustion energy. In line with the spirit of renewable energy in waste or waste processing technology projects in Indonesia, it is an important task for the government and society, especially to destroy waste materials that have no use value. Almost several potential cities are encouraged to develop and create alternative fuel production from waste. The production process certainly requires a production process standard that must be determined so that the operation of processing waste into fuel becomes optimal. The problems in various cities are almost the same about how waste can be decomposed (Eyad Batarseh, M.A. 2018). It is very important that machines and equipment for waste processing equipment are prepared properly. Tool/machine constraints are important considering the production process is running well. The purpose of the machine to process waste into RDF is produced by processing waste through a process of homogenizers into small size/granules (pellets) which can then be used for renewable energy sources in the process of burning a substitute for coal. The waste processing machine that produces RDF has the main parts, namely:

- Conveyor belt to move waste material from below to the top of the hopper.
- A shredder machine is a machine for chopping waste material in the form of plastic, wood, and other particles contained in waste
- Ballistic separator is a separator component between metal and ordinary waste

A waste processing machine definitely requires optimal performance in order to increase its production capacity. In particular, each component must be ready and able to work optimally according to its function. Constraints in the operational process of the chopping machine are sometimes clogged with wet waste so it needs maintenance so that the machine performance is optimal accurately after calculating the OEE of the machine, it is certain that the key performance indicator can be determined. Each machine definitely needs periodic maintenance optimally so that the production machine can run well. Planned maintenance aims to maintain engine performance so that it can be used optimally based on its effectiveness. One of the efforts to restore engine performance is to carry out routine maintenance up to overhaul. The machine repair process requires several stages of work including inspection, damage identification, disassembly, measurement, setting/installation and machine testing.

## II. RESEARCH METHODS

The research design used an experimental design sequence with survey stages at the final disposal site or abbreviated TPA, checking or inspecting machine tools, measurements, analysis of inspection results carried out using a qualitative descriptive approach accompanied by quantitative results according to the facts in the field.

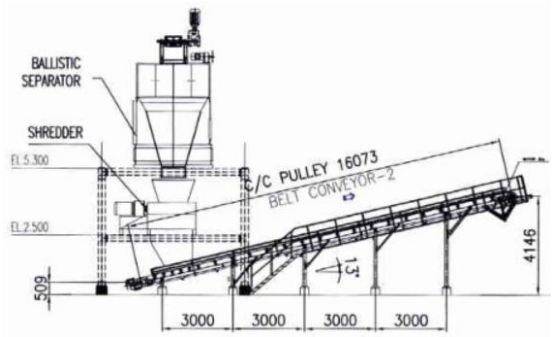


Figure 1. Technology for processing waste into RDF

In this experiment, several RDF production equipment were determined to be used as objects as well as research samples including:

1. Weighing trucks
2. Excavators
3. Conveyor belts
4. Shredder machine
5. Ballistic separator
6. Generators of electricity
7. Dreyer or dryer
8. Electric motors

The data collection technique is carried out by checking the RDF production technology using several measuring instruments/test kits that can check the condition of the above equipment or equipment (Mujayyin et al. 2021).

The stages of checking RDF production equipment are as follows;

- Check engine vibration
- check the lighting area of the RDF machine
- checking alignment (shaft, coupling, engine run out, or checking engine rotation stability)
- check the sound of the engine and detect sounds in machine parts such as (bearings, shafts, reducers) so that mechanics can know very clearly from the shock in the ear
- check the condition of the shaft, between the main axis of the electric motor and the shaft being rotated and to obtain centricity so that it does not cause friction, vibration and other factors.

The standard for processing waste into alternative fuels or RDF which comes from waste material that is not useful is turned into waste and then sorted/sorted, filtered, destroyed in the shredder process, separated liquids and oil, to become an alternative fuel that can be used for combustion energy in cement factories (Hasan R. 2018). After determining the standard production process according to the results of the study, the process flow process is obtained as follows


Figure 2. RDF process flow

The process of processing waste into RDF starts with a weighing truck, the garbage is loaded on the truck, then when unloading it is sorted by the waste management business by waste pickers. treatment area on the shredding machine after being chopped, heated or dried by bay drying, the RDF collection process is ready to be sent to the waste storage using a loader and transported by truck. Rdf is ready to be put into the hopper of the conveyor belt transport device to be put into the kiln as a combustion supply in the industry (Hasan MK. 2021).

To increase production on tools or machines from previously known damage, time efficiency and production costs, increase productivity, to meet customer needs, achieve optimal machine utility and get better results in terms of production and service with the six sigma DMAIC method

The six sigma DMAIC method is a method of increasing production from minimizing known causes of damage, time efficiency and production costs, increasing productivity, meeting customer needs, achieving optimal machine utility, and getting better results in terms of production and service (Hanky Franciscus, 2014 ). In the define stage, critical things have been identified in the production equipment shredder machine. The second measure measure has obtained the value of RDF production from the results of measuring and evaluating the conditions of the RDF production process, thirdly a causal analysis has been carried out of the problems that exist in waste processing technology, especially shredders with fishbone diagrams, fourthly recommendations for improvements to reduce the damage that occurs has been designed. In the fifth stage, calculating the sima quality level and comparing the quality level before and after the repair is carried out by testing the post-improvement hypothesis.

Checking the condition of waste processing equipment by calculating the OEE (Overall Equipment Effectiveness) value. The objective of OEE is as follows;

- The OEE value of a machine can be used as a parameter for the problematic engine condition
- The machine works alone on the process, so the OEE value can identify which machine is the most effective and which is less than optimal. (Hasrul M. et al. 2017).

Key performance indicators (KPI) in this case are measurable steps that are generally taken by companies in measuring the performance of waste processing machines from time to time. Determination of KPIs and targets is very important so that it is precise in determining the preparation of quality objectives including focusing on which units will be developed each period. The first thing that must be determined is the perspective consisting of the productivity of the RDF production business unit, machine performance, maintenance of production equipment, and product defects. Quality objectives include increasing the amount of RDF production, increasing OEE value, having maintenance personnel (mechanics), reducing maintenance costs, providing maintenance tools/parts, conducting inspections/quality control, indicators of success, units, weights, and targets (Wakhid et all. 2020).

## III. RESULTS AND DISCUSSION

The results of the performance of the waste processing machine take into account the values obtained from the tests after improving the performance characterization of the technology for processing waste into RDF and OEE analysis in the production of processing waste into RDF fuel (Wahyu et al. 2021). After all data on production working hours, total production, number of defective products and RDF production machine downtime have been recorded, the level of effectiveness can be calculated. To calculate the level of effectiveness, availability, performance and quality values are needed.

B. Calculation of Overall Equipment Effectiveness (OEE) Value

The calculation of the OEE value starts from calculating the percentage value of the Availability ratio, then calculating the value of the Performance ratio, and calculating the percentage of quality ratio. It is obtained that the average working hours for each employee in one shift is 480 minutes/day so if allocated monthly with an effective time of 25 days the allocation of working hours is 12,000 minutes, while the RDF production process in one package takes 34 minutes and obtained data from the field that the total production produces RDF from August 2019-July 2020 and there is also data on failures in RDF production or defects as follows.

Table 1. Number of production and failures in RDF production in August 2019-July 2020

| Bulan | Jumlah Produksi (ton) | Defect Amount (ton) |
|---|---|---|
| August | 74 | 6 |
| September | 76 | 2 |
| October | 79 | 3 |
| Nopember | 80 | 0 |
| December | 70 | 7 |
| January | 73 | 6 |
| February | 76 | 7 |
| March | 79 | 0 |
| April | 71 | 5 |
| May | 82 | 0 |
| June | 78 | 8 |
| July | 75 | 4 |

RDF production does not require a time target and total production capacity, but waste processing machines must continue to operate and good maintenance management is needed so as to reduce down time and reduce waste as much as possible. Production failures are usually caused by material getting stuck in the shredder blade so that it stops momentarily when the machine is operating. The results of calculating the availability of waste processing machines into RDF using the calculation formula (1) are produced as follows in table 4.

Based on the calculation and recording of the machine's ability to produce RDF from January to December, the average machine can operate without interruption at 85.30%. Calculation of availability in August 2019 as follows;

$$Availability\ ratio = \frac{operating\ time}{loading\ time}$$

$$= \frac{9900}{12000}$$

$$= 82{,}50\ \%$$

Based on availability calculations in August 2019, the percentage of RDF production machine availability is 82.50%, the time availability ratio level for RDF production machines.

If the calculation above is implemented in the following month with the same calculation, it will produce an availability ratio value as shown in table 5 below

Table 2. Calculation of the availability ratio for August 2021-July 2022

| Bulan | Loading Time (menit) | Total Unplanned Downtime (menit) | Operating Time (menit) | Availability Rate (%) |
|---|---|---|---|---|
| August | 12000 | 2100 | 9900 | 82,50 |
| September | 12000 | 1500 | 10500 | 87,50 |
| October | 12000 | 1700 | 10300 | 85,83 |
| Nopember | 12000 | 1400 | 10600 | 88,33 |
| December | 12000 | 2000 | 10000 | 83,33 |
| January | 12000 | 1600 | 10400 | 86,67 |
| February | 12000 | 1300 | 10700 | 89,17 |
| March | 12000 | 2075 | 9925 | 82,71 |
| April | 12000 | 1800 | 10200 | 85,00 |
| May | 12000 | 1900 | 10100 | 84,17 |
| June | 12000 | 1750 | 10250 | 85,42 |
| July | 12000 | 2050 | 9950 | 82,92 |
| Rata-rata | | | | 85,30 |

In calculating the availability ratio in October and February, it increased by 88.33% and 89%. While the overall average in one year the availability ratio is 85.30%. While the calculation of the Performance Ratio if implemented with the following formula;

$$Performance\ ratio = \frac{proceed\ amount\ x cycle\ time}{operation\ time}$$

$$= \frac{74\ x\ 35}{9900}$$

$$= 26{,}16\ \%$$

Based on the calculation of the performance ratio of RDF production machines in August of 26.16%, if you count all of them every month, the results of the performance of RDF production machines will appear in table 6 below

Table 3. Performance ratio calculation

| Bulan | Operating Time (menit) | Proceed Amount | Ideal Cycle Time | Performance Ratio |
|---|---|---|---|---|
| August | 9900 | 74 | 35 | 26,16 |
| September | 10500 | 76 | 35 | 25,33 |
| October | 10300 | 79 | 35 | 26,84 |
| Nopember | 10600 | 80 | 35 | 26,42 |
| December | 10000 | 70 | 35 | 24,50 |
| January | 10400 | 73 | 35 | 24,57 |
| February | 10700 | 76 | 35 | 24,86 |
| March | 9925 | 79 | 35 | 27,86 |
| April | 10200 | 71 | 35 | 24,36 |
| May | 10100 | 82 | 35 | 28,42 |
| June | 10250 | 78 | 35 | 26,63 |
| Juli | 9950 | 75 | 35 | 26,38 |
| Rata-rata | | | | 26,02 % |

The highest percentage value in March experienced an increase of 27.86%, the average performance value of the RDF production machine was 26.02%, which was very low because production machines experienced enumeration difficulties in the rainy season because garbage and other materials were classified as unable to be enumerated/ destruction. To avoid machine damage and expensive maintenance costs, the production process was stopped and cleaning and repairs were carried out. The quality ratio value gets the following calculation results ;

$$Quality\ ratio = \frac{proceed\ amount\ \ x\ defect\ amount}{proceed\ amount}$$

$$= \frac{74\ \ x\ 6}{74}$$

$$= 65{,}89\ \%$$

Based on the calculation of the quality ratio of RDF production machines in August of 65.89%, if you count all of them for each month, you will see the results of the quality of RDF production machines shown in table 7 below.

Table 4. Quality ratio calculation

| Bulan | Deffect Amount | Proceed Amount | Quality ratio |
|---|---|---|---|
| August | 6 | 74 | 65,89 |
| September | 2 | 76 | 73,37 |
| October | 3 | 79 | 75,20 |
| Nopember | 0 | 80 | 80,00 |
| December | 7 | 70 | 60,00 |
| January | 6 | 73 | 64,78 |
| February | 7 | 76 | 66,79 |
| March | 0 | 79 | 79,00 |
| April | 5 | 71 | 63,96 |
| May | 0 | 82 | 82,00 |
| June | 8 | 78 | 67,74 |
| July | 4 | 75 | 69,67 |
| Rata-rata *Quality ratio* | | | 70,70 |

**B. Calculation of Overall Equipment Effectiveness Value**

The OEE value on RDF production machines can be calculated using the formula for the three variables above, namely availability, performance, and quality. As the result of the calculation as follows

OEE = Availability ratio x Performance ratio x Quality Ratio
= 85,30 x 26,03 x 70,70
= 15,69 %

A comparison of the ratio values of availability, performance, quality, and OEE of RDF production machines with the JPIM (Japan Institute of Plant Maintenance) standards can be seen in Table 5. From this table it can be seen that the OEE value is far below the JPIM standard. The low OEE value of the RDF production machine is affected by the low performance ratio value. Analysis of the causes of the low RDF engine performance ratio is due to the planning factor for alternative fuel factory facilities which are classified as relatively inadequate so that the equipment cannot support the production or maintenance process, especially in drying small waste bins and the waste that comes from the countryside must be mixed Mix sand, food scraps, plants, and other organic leaves so that it is difficult to enumerate according to the ideal cycle time.

Table 5. Calculation of the OEE value of post-repair RDF production machines

| Parameter | Mesin Produksi RDF | Standar Dunia |
|---|---|---|
| Availability ratio | 85,30 | 90,00 |
| Performance ratio | 26,03 | 95,00 |
| Quality ratio | 70,70 | 99,00 |
| OEE | 15,69 | 85,00 |

The target OEE value for RDF production machines after repair and maintenance of all technical aspects and production planning will improve the OEE value by managing improvements to machine damage, machine settings, small stops, slow running, start-up defects and production defects. Meanwhile, the performance ratio was set at 76.03%, so that a new standard OEE value of 45.85% was obtained.

Table 6. Calculation of performance after repair of RDF production machines**.**

| Bulan | Operating Time (menit) | Proceed Amount | Ideal Cycle Time | Performance Ratio |
|---|---|---|---|---|
| August | 9900 | 80 | 35 | 28,28 |
| September | 10500 | 100 | 35 | 33,33 |
| October | 10300 | 110 | 35 | 37,38 |
| Nopember | 10600 | 150 | 35 | 49,53 |
| December | 10000 | 200 | 35 | 70,00 |
| January | 10400 | 400 | 35 | 134,62 |
| February | 10699 | 442 | 35 | 144,59 |
| March | 9925 | 350 | 35 | 123,43 |
| April | 10200 | 160 | 35 | 54,90 |
| May | 10100 | 204 | 35 | 70,69 |
| June | 10250 | 320 | 35 | 109,27 |
| July | 9950 | 160 | 35 | 56,28 |
| The average performance ratio after repair | | | | 76,03 |

The important point is how to make the RDF engine run optimally so that performance can be high, one of which is reconditioning the engine like a new machine. Implementation of maintenance is carried out consistently and effectively so that machine problems will be detected before the RDF production machine is put into operation. The amount of loss that affects performance is momentary error and low speed.

7. The new OEE value after the repair and improvement of the RDF production process was carried out

| Parameter | Mesin Produksi RDF | Standar Dunia |
|---|---|---|
| Availability ratio | 85,30 | 90,00 |
| Performance ratio | 76,03 | 95,00 |
| Quality ratio | 70,70 | 99,00 |
| OEE | 45,85 | 85,00 |

Even though the above is still below the JIPM standard value, this new standard has increased by around 30.16% from the previous one.

The results of checking on the critical part or on the critical part of the equipment technology for processing waste into alternative fuels that are damaged are identified. Diagnosis of damage by means of measure, namely by measuring the performance of the machine through several parameters of the type of checking which can be seen in the table of equipment inspection results as follows:

1. Visually inspecting using the inspection checklist found damage to the electric motor and chopping blades on the shredder
2. Checking the lighting using a lux meter, the lighting level is 230 lux and it meets the standard lighting level
3. Checking the run out of the shaft-coupling driven shaft is still said to be normal threshold from the allowable tolerance
4. checking the alignment of the machine components on the ballistic separator has been successfully aligned5. detect engine sound using a sound level meter for noise levels between ±70 dB to ±90 dB
6. Deteksi bunyi nois pada (bearing, shaft, reducer) menggunakan stetoskop getaran pada tataran normal motor, reducer, balistic 7-8 A
7. Checking the RDF size, the rdf size is 25.05 mm long x 12.05 mm wide
8. Coupling axis alignment settings using Al 2000 vertical -0.111 and 0.048 horizontal -0.057 and -0.048
9. Check the air humidity around the WTZ area, the TPA environmental temperature is around 30-35 0C

10. Check engine vibration using a vibration meter with a frequency between 350-375 Hz.

Problems that occur based on the results of the inspection show that one of them is the measurement of the performance of the shredder after routine and periodic repairs are carried out with the aim of obtaining or knowing damage that has occurred to a machine early so that with this information data we can schedule a repair or service of a machine.

The graph of the results of testing the performance of the shredder machine for chopping TPA waste before reconditioning/repair is carried out can be read as the production capability generated based on the fact that the operation of the shredder machine can be done automatically or manually. Auto or manual operation is related to the safety of the tool. Because there had been a halt in the rotation of the blade shaft due to excessive loads, the operator temporarily stopped reconditioning.

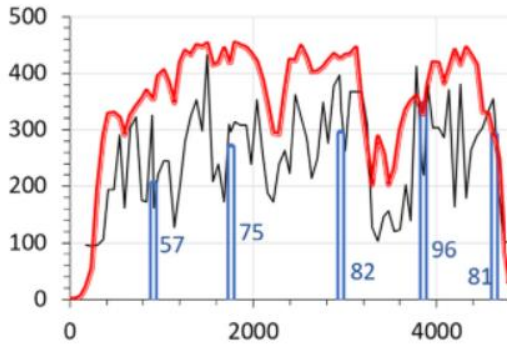


Figure 3. Graph of shredder machine performance

The operating standard and the shredder machine are improved to increase the working function of the shredder machine to operate well in chopping or destroying waste and can be put into the combustion kiln from the calculation of the operating process of the shredder machine, it is obtained up to 4 tons/day for shredding results for a week with 5 working days according to optimization productivity performance of employees and machines. Compilation of performance indicators in the production process of processing landfill waste into alternative fuels is the final stage in this research. This step is intended to determine what things are needed to measure a performance measurement system. The design of the proposed performance indicators can be seen in the table below and the data on the size of the proposed performance indicator designs is obtained and determined on the equipment or equipment performance references that have been obtained from one of the opinions of employees in the RDF production business.

Table 8. results of recapitulation of KPI weighting values

| **(KPI)** | **SATUAN** | **TARGET** | **NILAI** |
|---|---|---|---|
| Production capacity | Ton/hr | 5 | 4 |
| Distribution of RDF to Factories | Kali/hr | 2 | 2 |
| *Availability Ratio* | % | 99 | 85 |
| Performance Ratio | % | 99 | 83 |
| Quality Ratio | % | 99 | 86 |
| Mechanical count | Orang | 2 | 1 |
| Increased inspection | Kali/hr | 2 | 2 |
| Decreased Downtime | Kali/bulan | 5 | 2 |
| Jumlah Perawatan Number of periodic maintenance | Kali | 5 | 3 |
| Number of tools/parts | Unit | 20 | 10 |
| Product Defect | Ton | 10 | 5 |

Of the 11 proposed KPIs, an average value has been obtained that is not much different based on goals, sizes, targets and initiatives to achieve targets but from a perspective towards improvement in each indicator. So that

the overall performance of the waste processing technology into RDF increases which has an impact on increasing the profile of the RDF production business for the supply of combustion energy for the cement industry in particular.

## IV. CONCLUSSION

The operation of a machine for processing landfill waste into an alternative fuel for RDF has a capacity of 4 tons/day, an increase in the range of 1 ton after repairs are made to keep the machine running properly requires periodic maintenance. Failure analysis in the operation process of the shredder tool is influenced by; operator, machine operating system, method of operation, and material selection that is ready to be chopped.
While determining key performance indicators for determining KPI targets on the RDF production target, production capacity reaches 4 tons/day.

## DAFTAR PUSTAKA

[1]. Eyad Batarseh, M.A 2018 Analysis of Refuse Derived Fuel Utilization from Aqba Municipal Solid Waste. Jordan Journal Of Civil Engineering, Volume 12, No. 2 Pages 245-253
[2]. Farid Mujayyin, Dea Argita Gunarso, 2021 Performance of Landfill Waste Processing Machines into Refuse Derived Fuels using the Six Sigma DMAIC Method, Nozle: Journal of Mechanical Engineering (NJME), Vol. 10, No.1, ISSN: 2301-6957
[3]. Wahyu, et al. 2022 Performance Characterization of a 5 KW Diesel Generator Using Wood Powder Syngas with Load Variations. Journal of Renewable Energy & Mechanics (REM) Vol. 05 No. 01 2022: 34-43
[4]. Hanky Franciscus, C.P. 2014. Implementation of the Six Sigma DMAIC Method to Reduce Paint Bucket Defects at PT X. Journal of Industrial Systems Engineering, Vol. 3, No. 2 Unpar, p. 53-64
[5]. Haryanto, M.T 2014 Evaluation and Optimization of Waste Management Operational Engineering Management System (case study: West Ungaran district, East Ungaran district). Diponegoro University Repository, p. 54-61
[6]. Hasan R. 2018 Guidelines on the Use of Refuse Derived Fuel in Various Industries. India: Ministry of Housing and Urban Affairs (MoHUA)
[7]. Hassan, M.K 2013. Applying Lean Six Sigma For Waste Reduction in a Manufacturing Environment. American Journal of Industrial Engineering, Vol. 1, No.2, Pages 28-35
[8]. Hasrul, M. Jihan Shofa, Heru Winarno 2017 Analysis of Roughing Stand Machine Performance Using the Overall Equipment Effectiveness (OEE) and Failure Mode Effect Analysis (FMEA) Methods. INTECH Journal of Industrial Engineering Serang Raya University Vol. 3 No. 2, p-ISSN 2407-781x. matter. 55-60
[9]. Nugrahadi, Farid Mujayyin, Luwi Adi 2021 Productivity of Cement Factory Waste Heat Recovery Power Generation (WHRPG) Power Plant, Proceedings of the 11th Unwahas National Science and Technology Seminar, ISBN: 978-602-52386-5-9, D1, p. 1-10.
[10]. Wakhit Ahmad Fahrudin 2020 Analysis of Performance Measurement Using a Balanced Scorecard to Determine Key Performance Indicators at PT Mulia Artha Anugerah, JTMI Vol. 3 No. 1, p-ISSN: 2620-5793. matter. 15-23
[11]. Wahyu1, Erwin1, Slamet Wiyono1 2021 Performance characterization of 5 KW Diesel Generator Using Sawdust Syngas With Variation Of Loading, Journal Renewable Energy & Mechanics (REM) Vol. 05 No. 01 2022: 34-43 DOI: 10.25299/rem. 2022 vol 5 (01).8888