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RESEARCH ARTICLE

PRODUCTION AND PRODUCTIVITY IMPROVEMENT THROUGH EFFICIENCY SUGAR MILL

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Abstract

The indicator of sugar mill efficiency is the yield represented by sugar mill performance (technical efficiency), sugar cane plantation (sugar cane quality), and productivity. The scenario developed to formulate production process based on gap analysis. The objective of the study was to compare the production and productivity of sugar mills through improvement efficiency. The method used in this research was quantitative descriptive method, making a description of the relationship between sugar yields determinant variables, including (1) determination of gap analysis on a benchmark, (2) prediction of sugar yields and bagasse using multiple linear regression, (3) energy calculations with NCV (Net Caloric Value) approach, and (4) partial productivity measurement. The results showed that scenario 3 increased the yield to 10.4% with an increase of white crystal sugar production by 24%, while scenario 2 increased the yield to 9.3% with an increase of white crystal sugar production by 11.7% compared to scenario 1. Increasing the efficiency of milling extraction (ME) capable of increasing the energy potential of 4.3 kWh. Improving the technical efficiency of the factory resulted in increased productivity of raw materials of 0.029 tons white crystal sugar/tons, productivity of machine work hours of 5.29 white crystal sugar per work hours, sugar productivity to the land of 1.79 tons white crystal sugar/ha and energy productivity 4.27 kWh/tons bagasse (R-value as a validation test prediction model is 97.1% and 72%).

Introduction:-

The sugar industry is known as an industry that supplies its own energy (self-sufficiency energy) because the sugar industry produces White Crystal Sugar (GKP) as main product and bagasse as biomass. The sugar industry is known as an industry that supplies its own energy (self efficiency energy) because the sugar industry produces GKP as main product and bagasse as biomass [1]. Sugar production process in the plant through several stages including extraction, purification, evaporation, crystallization, centrifuge, drying and finishing. The inefficient process of sugar production indicates a disruption of material components and energy that come out and affect the environment [2]. The efficiency level of sugar factory is represented by the condition of factory performance. Yield, season, capacity utilization, sugar content, sugar recovery, sugarcane fiber, factory extraction reduction, reduction of overall extraction, molasses recovery are the main performance indicators for cane plant operation. Performance indicator

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shows the overall efficiency of a sugar mill in producing GKP. With inefficiency, the resulting sugar becomes less than the production target, so does the yield. The production of the Indonesian sugar industry is unable to meet Indonesia's sugar consumption. This can be known from the yield value of sugar produced. Yield represents the sugar that obtained during the production process. Yield is the weight ratio of crystal sugar (sucrose) to the weight of cane milled. The yield number represents sugar cane plantation performance and sugar mill performance. Refinement of yield is carried out by increasing the sugar content (pol of sugarcane) and decreasing the loss sugar during the process (improving technical efficiency). Loss of sugar during the process occurs because it is carried in bagasse, filter cake and molasses [3]. Increased sugar production can be done by improving engine performance to run optimum process [4]. Accomplishment yield Belle Vue Mauritius sugar factory in 2011 had a better performance achievement with 10.53% yield [5], [6] while Ngadirejo achieves the highest yield 8.69% in 2012 (factory data 2011-2015). The inefficiency in PG Ngadirejo is resulted in low performance compared to Mauritius due to inefficiency process so that the production target was not fulfilled. In addition, the bagasse produced by Mauritius sugar mill is higher than that of Ngadirejo sugar mill.

The main production from sugar mill is white crystal sugar and the by-product of bagasse, molasses and filter cake. The level of sugar productivity is influenced by the quality of sugarcane (in-farm) and the efficiency of the factory (off-farm). The by-product of sugarcane industry is bagasse, filter cake, and molasses. According to [7], sugarcane is categorized as an effective plant that can convert solar energy into chemical energy in the form of biomass. Biomass produced at least 100 t ha-1 in less than 1 year. Thus, the biomass is a renewable energy source that has a potential source of electrical energy for sugar mill. The production of electrical energy will generate added interesting economic value [8], [9], [10]. Biomass development as electrical energy refers to Article 4 of Law No.20 of 2002 on electricity and power plant operation guidelines contained in the Decree of the Minister of Energy and Mineral Resources No.02 of 2002 [7]. So that required the performance evaluation of Ngadirejo sugar mill on GKP and bagasse product.

Sugarcane is produced through vegetative propagation by using two buds or three buds. The first corp is called sugarcane harvested between 8 to 24 months after planting while the ratoon comes from the stalk of the sugarcane plant that remains underground, usually cut after 12 months. This cycle is repeated and lasts between four and ten years. Sucrose content and harvested crops decrease sometimes with ratoon because the land preparation for ratoon is not as comprehensive as in sugarcane [11], [12], [13]. Sugarcane quality such as sucrose, sugarcane hygiene and fiber content affect the amount of sugar extracted from sugarcane and also the quality or purity of juice [14]. The cleaner sugarcane makes an easy extraction of sugar from sugarcane and produces juice with high purity. If the fiber content is high, the amount of bagasse is greater so that the loss of sucrose in the bagasse increases. The recovery of sugar from raw juice is largely a function of purity of juice, or rather the impurity or nonsucrose content. Nonsucrose quantity directly determines the amount of molasses produced and the lost sucrose in molasses is usually proportional to the number of molasses and influenced by the impurity properties [15]. The fresh sugarcane is if the waiting period since sugarcane is cut down until it is milled at least 24 hours. Clean sugarcane means if it is free from dirt like soil, young sugar cane (sogolan), sugarcane buds (momol), dried leaves (daduk), roots, and non-cane manure. Clean sugarcane tolerance less than 5% of the impurities [16].

To determine inefficient performance, gap analysis is needed to be done on each performance parameters of the sugar mill. Sugar mill performance measurement is defined as the quantify the efficiency and effectiveness process from an action [17], [18], [19]. Performance measurement system using benchmarking approach, it can be used to improve the performance in various areas [20]. Benchmarking is a process for measuring the best company performance in its class and using analysis to meet and exceed the company.

Sugar mill technical efficiency determination is based on technical indicators [21]:

1. Mill extraction (ME). The work of milling station ME is illustrated sugar percentage that successfully extracted in raw juice on the sugar contained in the sugarcane.
2. Boiling House Recovery (BHR). The work of the processing station is represented as BHR that show as real sugar percentage obtained from sugar in the raw juice.
3. Overall Recovery (OR) shows the combined performance results between the mill station (ME) with the processing station (BHR). OR efficiency reflects the efficiency of sugar mill because it describes the amount of sugar that can be obtained from sugarcane.
4. Pol of sugarcane shows the amount of sugar dissolved in every 100 grams solution.
5. Yield is sugar weight ratio produced by each milled sugar cane.

The objectives of this research were (1) to analyzed the gap result on the benchmark, (2) to understand and analyzed the prediction value of yield produced by Ngadirejo, (3) to calculate and analyze the GKP, bagasse and energy obtained by PG Ngadirejo, (4) calculate and analyze productivity partially of Ngadirejo sugar mill. Sugar mill performance evaluation is reported by several stages: (1) situational analysis of Ngadirejo and Mauritius by knowing the gap value on internal and external benchmark in similar company; (2) sugar yield prediction by multiple linear regression approach and (3) calculation of GKP value, bagasse, and energy with NCV (Net Caloric Value) approach and (4) partial productivity measurement.

Materials and Methods:-

The method used in this research is quantitative descriptive method, description systematically, factual and accurate about the relationship between variables determining of the yield. Stages and procedure of data processing include gap analysis, yield, GKP and bagasse production, sugar and bagasse productivity.

Determination of Gap Analysis on Benchmark:-

Gap analysis is to compare the actual condition of parameters quantity in Ngadirejo against the benchmark Mauritius sugar mill. Benchmark in this study is a good practice or best practice among the internal benchmark in its own environment as well to practice on other external benchmark.

Based on mass equilibrium, technical efficiency evaluation and gap analysis are done against the benchmark analysis. Further analyzed and developed energy potential of sugar mill as energy source and water. Estimated net energy by conversion the energy used to energy unit (Joule). The method of calculating the gap analysis and technical efficiency shown in equations 1 and 2 that integrated with the technical formulation refers to [22].

$$OR = \frac{\text{Pol GKP}}{\text{Pol of cane}} \quad (1)$$

$$\text{Gap (\%)} = \left(\frac{\text{performance of sugar mill industry}}{\text{Benchmark}} \times 100\right) - 100 \quad (2)$$

Sugar Yield and Bagasse Prediction:-

Sugar industry has parameter or indicator of production process efficiency especially in the manufacturing or processing of sugar cane at the mill. The Miller's technical efficiency indicator (Mill Extraction, Boiling House Recovery, Overall Recovery, sugarcane and yield), while the parameters for sugarcane quality (sugarcane pol, sugar juice content, fiber, and trash). The white crystal sugar yield (GKP) is a measure of the performance of a sugar mill efficiency using a method that developed by ISST (International Society of SugarCane Technologists). Technical efficiency of sugar mills determinant used by sugar mill is based on technical indicators [21] as the basis for preparation of multiple linear regression equations.

$$Y = aX_1 + bX_2 + cX_3 \ldots + C \quad (3)$$

Where Y is % yield that will be predicted as the dependent variable. Furthermore, X1, X2, X3,...,Xn is mill extraction, boiling house recovery, pol of sugarcane as the independent variable. Modeling will generate a coefficient of efficiency and the value of independent variable value using the principle of linear regression with Microsoft excel and prediction validate test based on R-Square.

Refer to [23] state that the multiple linear regression aims to examine the effect of two or more independent variables (explanatory) to a dependent variable. This model assumes a straight line relationship between the dependent variable with each predictor. This relationship is assumed in the formula. Regression statistical program can generate three outputs, statistical regression, ANOVA tables, and information about ß. Simple linear regression is linear regression which estimates the magnitude of coefficients from linear equations involving one independent variable. Multiple linear regressions are a linear regression that estimates the magnitude of coefficients from linear equations, involving two independent variables to calculate the magnitude of the effect of two independent variables on a dependent variable.

Calculation of White Crystal Sugar, Bagasse and Energy:-

The self efficiency energy in sugar industry produce bagasse as biomass and also apllied in Palm Oil Mill and rice mill [24], [25]. All Calculation of white crystal sugar and bagasse of Ngadirejo sugar mill based on secondary data (amount of sugar cane value, pol of sugar cane, mill extraction, and boiling house recovery in 2011-2015. The data used as a basis to know the performance condition of the sugar factory and also as a basis to do a simulation with integrated in yield prediction (Equation 4) and will get the value of white crystal sugar (ton). Furthermore, the calculation of bagasse value produced by using NCV formulation refers to [26] with the assumption of 50% moisture value [27]. Data processing using Microsoft excel and validation test using graphical validation by knowing the R-Square value.

$$\text{GKP (ton)} = \text{predict of yield (\%)} \times \text{production of cane (ton)} \quad (4)$$

$$\text{Bagasse (ton)} = \text{Bagasse (\%)} \times \text{production of cane (ton)} \quad (5)$$

$$\text{NCV} = 4250 - (12 \times \%\ \text{pol bagasse}) - (48.5 \times \%\ \text{humidity}) \text{ kcal/kg} \quad (6)$$

$$\text{Energy (MJ/kg)} = 0.0041868 \text{ MJ/kcal} \times \text{NCV} \quad (7)$$

Partial Productivity Measurement:-

Productivity calculation in each section of Ngadirejo sugar mill through productivity criteria in accordance with the existence of the part (objective) and allows combining all the important productivity criteria into a combination. Productivity measurement is done in partial productivity consisting of productivity of sugarcane, sugar, working hours, bagasse and sugarcane energy. Partial productivity measurement based on Ngadirejo sugar mill actual condition is as follows:

$$\text{Raw material productivity} = \frac{\text{Production of sugar (ton)}}{\text{Milling cane (ton)}} \quad (8)$$

$$\text{Land productivity} = \frac{\text{Production of cane (ton)}}{\text{Land (ha)}} \quad (9)$$

$$\text{Milling hours productivity} = \frac{\text{Production of sugar (ton)}}{\text{Milling effective (jam)}} \quad (10)$$

$$\text{Baggase productivity} = \frac{\text{Production of baggase (ton)}}{\text{Milling cane (ton)}} \quad (11)$$

$$\text{Sugar productivity} = \frac{\text{Production of sugar (ton)}}{\text{Land (ha)}} \quad (12)$$

Result and Discussion:-

Performance of Sugar Mill:-

Based on East Java Governor Regulation No.45 of 2006 regarding technical guidance of increasing sugarcane yield in East Java, sugar mill performance can be known based on OR, ME, pol of sugarcane and BHR [7]. Ngadirejo sugar mill performance in 2011 – 2015 showed that the performance has not been efficient compared to Mauritius. The results were obtained by comparing the value of sugar mill performance with the normal parameters of Ngadirejo and Mauritius production process which consist of sugarcane pol value, Mill extraction, Boiling House Recovery, and Overall Recovery.

These parameters are used as a reference to analyze the performance of sugar mills. Based on Table 1 the performance of Mauritius is better than Ngadirejo. It can be concluded that the efficiency level of Ngadirejo performance is less efficient than Mauritius. For the technical efficiency of sugar mills, Indonesia sets the Mill Extraction indicator achievement standard more than 96%, Boiling House Recovery more than 91%, Overall Recovery more than 87.5%, sugarcane more than 12% and yield more than 12%. This performance standard is still below of sugar mill achievement in other countries with sugarcane pol around 14-16% and yield between 13 to 14%.

Table 1:- Performance Gap of Ngadirejo on Mauritius Sugar Mill

Parameter	Proses	Ngadirejo[a]	Mauritius[b]	Gap
Pol of Sugar Cane	Pre milling	10.78	12.1	-11
Mill Extraction (ME)	Milling	92.61	97.5	-5
Boiling House Recovery (BHR)	Purification to centrifuge	82.67	98.9	-16
Overall Recovery (OR)	Milling to centrifuge	76.55	96	-20

[a]Actual Data Ngadirejo Sugar Mill (2011-2015)

[b]Mauritius Sugar Millin 2003 (Seebaluck *et al*,CARENSA/SEI 2008-02) [36]

Pol of sugarcane show the sugar content contained in cane juice. The value of sugarcane pol in Ngadirejo 10.78% is smaller than Mauritius that reached 12.1%. Gap acquired a negative value with a difference of 11 percent means that the achievement of Ngadirejo was below of the benchmark (Mauritius). Indonesian sugarcane pol averaged at a rate of 10% much lower than the world rate of 14 - 16%. This is due to the low number of sugarcane pol [28]. The value of sugarcane pol shows the quality condition of raw milled sugar cane is not yet on the optimal level of sugar content (sucrose) in sugarcane. This is caused by the maturity factor of sugar cane and sugarcane management that has been cutting down, sugar cane waiting period is too long to do the grinding process so it can cause the decrease of sucrose content.

The decrease of sucrose content influenced sugar produced by sugar factory. Although the process at the plant works efficiently, if the milled sugar cane has a low pol value, the resulting sugar yield is also limited. Sugarcane quality such as sucrose content, cane hygiene, fiber content affect the amount of sugar extracted from sugar cane and also the quality or purity of juice, tolerance is less than 5% of the impurities [14], [16]. In addition, the maturity of sugar cane is influenced by the genetic characteristics of the planted varieties, the age of sugarcane at the time of harvesting and climatic conditions when harvesting [29]. Mill extraction (ME) is the result of milking sugar process, a sugar mill is said to be efficient if the ME value is at a normal number around 95%. The ME shows the percentage of sugar that can be extracted from the sugar cane during the milling process. The bigger the ME value the more efficient the performance of the milling station. If the gap for the ME value is negative by 5% of margins, it means that the ME value of Ngadirejo sugar mill is beneath the benchmark. Ngadirejo mill extraction (92.61%) is smaller than Mauritius mill extraction (97.5%) and ME for Indonesian standard (95%). This shows that the extraction capability at the milling station is still inefficient in picking up the raw juice pol. The Less ME value is due to the condition of the milling machine is not good so the potential to stop milling for machine repair.

BHR of Ngadirejo is 82.67% below the normal number of 90% and smaller than Mauritius sugar mill 98.9%. BHR shows the percentage of real sugar obtained on sugar in raw juice from the processing station. This is due to a decrease in the performance of tools at the sugar factory in processing raw juice into white crystal sugar. The gap value between Ngadirejo and Mauritius is negative with a difference of 16, it means that Ngadirejo's performance is below than Mauritius with the difference of 16%.

OR is an overall performance assessment based on the ME and BHR scores. OR as an indicator of factory efficiency that has a normal standard value of 85%. The higher the OR the better the sugar mill performance. The OR value of Ngadirejo sugar mill is 76.55% smaller than its normal value and Mauritius sugar mill that reaches 96%. This means that the Ngadirejo's performance in producing white crystal sugar from sugarcane is inefficient because of losses to sugar cane pol of 23.5%. Pol that cannot be saved caused by loss and carried away by bagasse, filter cake, drip or unknown [30]. Gap value of the sugar mill reaches negative 20 means the achievement of Ngadirejo sugar mill is below of Mauritius sugar mill by 20%.

If performance analysis of sugar process technology using tolerance of 10% tolerance [7], then the sugar cane pol value, extraction is reduced and BHR are needed to understand as the contributing parameter of low yield value. The performance parameters of the sugar factory will affect the yield of the sucrose. Thus, the parameters are considered in the preparation of the yield prediction.

Prediction of Sugar Yield and Bagasse pol:-

Based on the achievement of gap analysis, production parameter is known as the contributor of low yield sugar value. To know the correlation and contribution of contributors to Ngadirejo yield value based on data from 2011 to 2015 using multiple regression analysis [31]. Regression and performance contribution of each production sector to the yield of Ngadirejo data is shown in Equation 13.

$$\text{Yield (\%)} = -13.39 + 0.74\,x_1 + 0.051x_2 + 0.11\,x_3 \qquad (13)$$

X_1 = Pol of cane

X_2 = Mill Extraction (ME)

X_3 = Boiling House Recovery (BHR)

The value of regression coefficient for the above variable is positive value means that if the sugarcane pol, ME, BHR variables increased by 1 unit then the yield value increased by 0.74, 0.051 and 0.11. It can be concluded that the higher the value of sugarcane pol, ME, BHR will affect the yield and yield of white crystal sugar production. The result of yield prediction on Eq. 13 is tested using R test to know the confidence level of the result of the yield prediction. The value of R test on the prediction simulation of yield value is obtained at 97.1%. Error value in each variable (X1 = 0.034; X2 = 0.033; X3 = 0.008). The value of pol has the largest contribution followed by BHR efficiency and ME efficiency (82.15%, 12.15%, and 5.71%). The acquisition of the estimated value of yield shows the percentage value of sugar produced by the company with the availability of sugarcane.

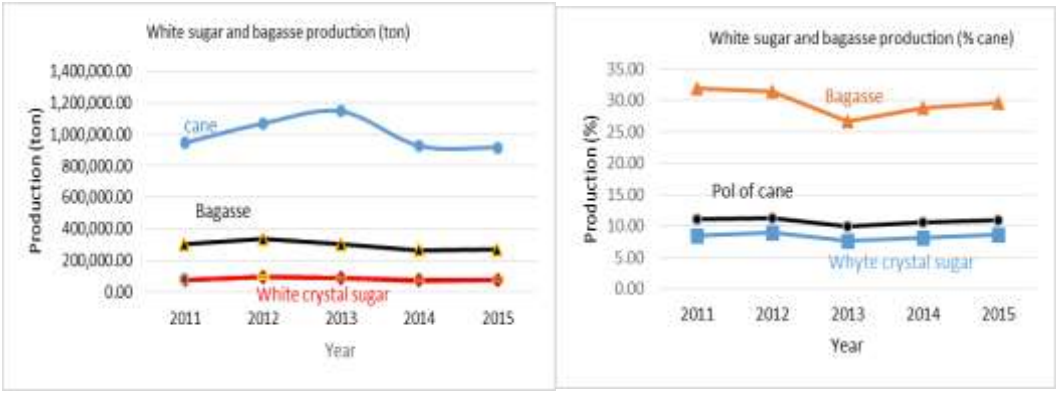
Regression and performance contribution of Mill Extraction to the sugarcane pol from Ngadirejo's data are shown in Equation 14. The value of regression coefficient for negative ME variables means that if the ME variables increase by 1 unit then the value of bagasse pol decreases by 0.06. This indicates that the higher ME will affect the decrease of the bagasse pol and the energy produced by bagasse.

$$\text{pol of bagasse (\%)} = -8.03 - 0.06\ ME \quad (14)$$

White Crystal Sugar (GKP) Production:-

Production is an activity to create or add the use of goods or services in order to achieve the prosperity of human needs. The White Crystal Sugar production is influenced by sugar yield value. The higher the yield, the higher the production of White Crystal Sugar. The yield prediction is used to know the value of sugar yield. Furthermore, the formulation of the GKP amount produced by the sugar factory with 3 scenarios. The first scenario, the GKP production based on the company's history for 5 years. The second scenario is the GKP production based on Mauritius sugarcane pol condition using Ngadirejo machine and scenario 3 based on Ngadirejo sugarcane using Mauritius machine.

The first scenario using 5 observations for simulation of White Crystal Sugar prediction. Observation 1st through 5th for White Crystal Sugar and bagasse production with production of sugarcane used assumptions based on data in 2011-2015. The average sugarcane production is 1.000.789 tons (Ngadirejo) and 4.000.000 tons (Mauritius). Simulation and actual result of White Crystal Sugar and bagasse production do not differ significantly (Fig. 1). Total of sugar cane, White Crystal Sugar, and bagasse in 2011-2015 in Ngadirejo tend to move fluctuating. The average value of white crystal sugar and bagasse are 83.623,58 tons and 296,464.20 tons respectively (8.37% and 29.7% of sugar cane). The production simulation validation test of White Crystal Sugar and bagasse with R2 is 97.1%.



(a) (b)

Fig. 1:- (a) The amount of cane, White Crystal Sugar and bagasse production (ton), (b) pol of cane, white crystal sugar and bagasse production (%)

The second and third scenario simulation by controlling the condition Mauritius sugar mill assumed for Ngadirejo sugar mill. The scenario 2 is the White Crystal Sugar production based on Mauritius sugar cane pol condition using Ngadirejo machine and scenario 3 based on Mauritius machine using Ngadirejo sugarcane pol condition. Preparation of the scenario assuming the conditions of the scenario and White Crystal Sugar production are shown in Table 2.

Table 2:- Preparation of scenario and GKP production

	Pol of cane (%)	ME (%)	BHR (%)	Yield (%)	GKP (ton)
PG Ngadirejo (Scenario 1)[a]	11	93	83	8.4	83,516.6
PG Mauritius	12	98	99	11.4	453,687.10
Scenario 2[b]	12	93	83	9.4	93,269.7
Scenario 3[c]	11	98	99	10.4	103,757.8

[a]Scenario 1, Ngadirejo sugar mill average Data (2011-2015)
[b]Scenario 2, Mauritius sugar cane pol condition using Ngadirejo machine
[c]Scenario 3, Ngadirejo sugar cane pol condition using Mauritius machine

In 2014 and 2015 sugarcane production declined and impacted on White Crystal Sugar production and bagasse that was also decline. This is due to the decline in the sugar cane production area and the performance of White Crystal Sugar production in Ngadirejo sugar mill. In 2013 the production of sugar cane and available land is bigger than in 2012, but the production of White Crystal Sugar and bagasse in 2013 is smaller than in 2012. In 2012 White Crystal Sugar production is 8.94% and bagasse is 31.5%. Meanwhile, in 2013 White Crystal Sugar production only reached 7.72% and 26.63% bagasse. The phenomenon that occurred in 2012 and 2013 due to the condition of machine performance and quality of sugar cane in Ngadirejo sugar mill was decreased.

Table 2 shows that the GKP production is influenced by ME, BHR, and sugarcane pol. If using the performance of Mauritius machine with Ngadirejo sugar cane pol value in the scenario 3 then the GKP value is bigger than the scenario 2. Based on the comparison with the actual condition of Ngadirejo (scenario 1), then scenario 3 increased the yield to 10.4% with the increase of GKP production by 24%, while scenario 2 increased the yield to 9.3% with the increase of GKP by 11.7%. With the effort to increase the sugarcane pol up to 14% and sugar processing using Ngadirejo sugar mill machine only able to increase the yield of 10.7% which means it is not able to compete with the result of Mauritius sugar mill yield.

The GKP production results based on the scenario can be concluded that the higher the number of milled sugar, the higher GKP and bagasse that can be obtained with the requirement of controlling the overall recovery performance, and the condition of the sugarcane quality. In addition, controlling the value of the bagasse pol value and mill extraction on milling machines. Bagasse pol should be in low water humidity conditions. Bagasse pol represents the condition of bagasse that can have an opportunity as an energy source. Sugarcane with high moisture will provide difficulties to generate energy. To some extent, the mill's speed at the sugar mills is related to management policies in response on equipment conditions and production targets, as there is a trade-off between the milling speed and the sugar losses of the mill stations, especially the sugar that found in bagasse. If roll rotation is accelerated, the milling capacity will increase, but the extraction rate will decrease since the bagasse time is under the pressure of the roll rollers to be shorter. In contrast, if it increases the extraction by slowing down the roll and increasing the water of the imbibitions, or raising the pressure, the milling capacity will decrease. The roll rotation that is too slow by will reduce the milling capacity [22].

The higher the imbibition temperature the more sugarcane juice that can be produced [32]. This is because the higher the temperature the more dilute sugar so that sucrose easily diffuses out and the production juice will be high. The imbibition temperature can affect the level of solubility of sucrose in warm conditions. Cell walls have semi-permeable power, where sugar can break out of the bagasse cells as long as the cell is alive. The purpose of providing high-temperature is to reduce fuel economy usage, accelerate the cell-cell splitting reaction due to high given imbibition temperature. This will also affect the performance of sugarcane milling machine which is represented by Mill Extraction in taking raw juice pol in sugarcane. Giving imbibition is also an attempt to suppress the loss of sugar in the bagasse.

Furthermore, mill extraction represents the condition of the ability of the milling machine to produce raw sugarcane juice. The condition of mill extraction below the standard value will affect the white crystal sugar production. The high acquisition of white crystal sugar production is influenced by the higher sugarcane pol, where the raw juice is affected by ME and sugarcane pol. The decrease of white crystal sugar production shows the low value of ME, BHR and OR [33]. Performance and efficiency indicators are strongly influenced by the total losses generated by sugar factories, in which the losses indicate a decrease in the performance of the tool's ability at the sugar mills to process raw juice into white crystal sugars, thereby decreasing the white crystal sugar production.

Energy Production based on Bagasse:-

Sugar factories not only get a profit from the sale of sugar production. However, sugar mills can utilize the by-products of bagasse for energy use for reuse by the company or to be sold. So the sugar mills can minimize the use of costs during processing and gain additional benefits from the by-products of sugar products. So the sugar mills can minimize the use of costs during processing and gain additional benefits from the by-products of sugar products. In addition, the use of bagasse as resources will affect the efficiency of the sugar production process. Thus, it is important to maximize both the white crystal sugar production and the bagasse that will be the source of energy. The higher the ME efficiency, the more it will increase the content of raw juice, which means the decreasing of the bagasse pol. The predicted results of bagasse and energy production for an average of 5 years did not differ significantly with actual data.

Decreasing of the pol of bagasse has resulted in a higher bagasse energy content. Calculation of sugarcane energy using Eq. 4-8 [26], [27]. Ngadirejo Sugar Mill produces an average bagasse of 296 482.17 tons per year with moisture value of 50%, and a pol value of 2.82 with ME = 92.57% efficiency, yields NCV = 1,791.16 kcal kg^{-1} equivalent to 7.50 MJ kg^{-1} or 2.08 kWh kg^{-1} of bagasse. The comparison of the actual average condition of Ngadirejo sugar mill with ME increase based on Mauritius sugar mill of 98% increased the bagasse energy to NCV = 1,794.82 kcal kg^{-1} equivalent with 7.52 MJ kg^{-1} or 2.09 kWh kg^{-1} bagasse. The energy potential of bagasse is 2.09 kWh kg^{-1} can replace 1 ton of coal with 4.7 tons of bagasse [34]. Thereby increasing the efficiency of the ME capable of raising the energy potential of 4.3 kWh per tons bagasse.

Actual data production of sugarcane, bagasse, and energy in Ngadirejo sugar mill tend to move fluctuating (Fig. 2). The bagasse production affects on energy produced. The highest white crystal sugar, bagasse, and energy production are 95,527.43 tons, 336,745.06 tons and 701,419.84 kWh. When compared with 2013 the production of bagasse and energy is smaller than in 2012, while sugar cane wide area and production in 2013 is bigger than in 2012. This is because the sugarcane pol value and sugarcane quality in 2012 is better than in 2013.

The phenomenon is due to the condition of the sugarcane quality to be crushed and bagasse moisture to produce energy. The bagasse can be used as fuel for boiler and energy sources. Factors that affecting bagasse are the condition of the milling machine and imbibition water supply. Milling machine according to roller size, roller amount, and roller rotation. In addition, hydraulic pressure will also affect the extraction process, where the bigger the pressure the bigger the juice produced from the extraction process. However, the magnitude of the hydraulic pressure must be balanced with the power of the roller mill rotation. The smaller the roller rotation then the juice will be easily removed from the roller, the roll becomes wet and the juice is sucked back by the bagasse. So the condition of bagasse produced will have a high humidity value. Bagasse with high humidity will be difficult to be re-processed into energy.

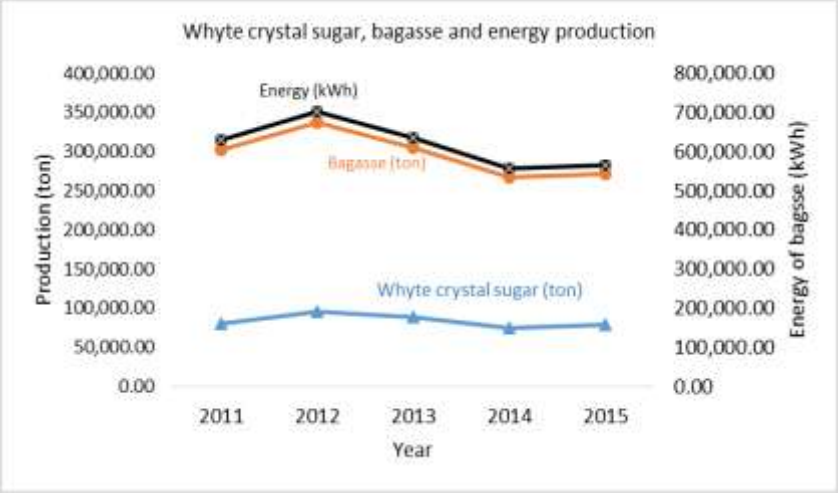


Fig. 2:- Production of white crystal sugar, bagasse and energy

Sugar Mill Productivity:-

Achievement performance can be seen from the productivity that generated by Ngadirejo sugar mill. Production, quality performance, is a component of productivity effort. Thus, productivity is a combination of effectiveness with efficiency [35]. The higher the predicted value of the yield, the higher the production. The high value of sugar yield shows that the performance of the sugar factory is optimal and efficient. Identification of productivity is done through efficiency assessment. Where productivity is a ratio between output and input used to produce sugar. The higher the productivity the higher the production of sugar. This is because the ratio of resource inputs such as machinery, sugarcane raw materials, additives used to produce sugar is used efficiently and effectively.

Measurement productivity by using the data input and output production of Ngadirejo based on historical data from 2011 to 2015. The number of inputs consisting of sugarcane, milling machine working hours affects the total productivity of white crystal sugar, bagasse, and energy. Partial productivity measures carried out according to the equation 8 to 12 include sugar productivity, the productivity of working hours milled (tons per hour), the productivity of bagasse, the raw material productivity, land productivity (tons per ha), and bagasse productivity energy. Measurement of productivity like performance value of each criterion based on the output value (sugar production) divided by input (raw materials and machine work hours). Performance value shows the number of products generated from each unit of used resources.

Table 3 shows the partial productivity values consisting of sugar productivity, milled hours, sugar, bagasse, sugarcane fields, and energy. Raw material productivity is the use of sugarcane (ton) to produce sugar (ton). Productivity of machine work hours is the use of machine work hours to produce sugar. Bagasse productivity is bagasse production divided by total use of sugarcane. The productivity of sugar is the production of sugar produced by sugar factories divided by the availability of land (ha). The productivity of sugarcane is the availability of land (ha) to generate sugarcane. Sugar production and productivity increases with increasing sugarcane pol and mill efficiency (scenario 2 and scenario 3). With the increase in technical efficiency factory in accordance with Mauritius sugar mill as benchmark showed an increase in productivity. Increased productivity of raw materials 0.02 tons white crystal sugar per ton sugarcane, productivity of working hours 5.54 tons white crystal sugar per milling machine, sugar productivity to the land 1.88 tons white crystal sugar per ha and energy productivity 2.77 MWh per ton cane (scenario 3).

Table 3:- Sugar mill productivity

Scenario	Land area (x1000ha)	Productivity					
		Sugar (ton/ha)	Milling hours (ton GKP/milling hours)	Sugar (ton/ton cane)	Bagasse (ton/ ton cane)	Land of cane (ton/ha)	Energy (MWh/ton cane)
Scenario 1	11.4	7.29	21.50	0.08	0.30	87.58	0.617
Scenario 2	11.4	8.13	23.98	0.09	0.30	87.58	0.619
Scenario 3	11.4	9.17	27.05	0.10	0.30	87.58	0.620

Ngadirejo's actual productivity data for 2011-2015 tends to move fluctuating. The decline in sugarcane productivity (tons ha-1) due to lower production of sugarcane is produced by farmers and the decreased motivation of farmers to plant sugarcane. Decrease in sugar productivity due to decreased technical efficiency of the plant and the value of sugarcane pol. The decrease in energy productivity is due to the increase of the bagasse pol value caused by the decreasing efficiency of ME. This performance ratio shows the actual productivity achieved by the factory of each criteria per year measured, it is showing that the highest performance ratio achievement for all three criteria is in 2012. Production and productivity are related to performance achievement of the sugar factory.

Conclusion:-

The gap results of Ngadirejo sugar mill on the benchmark (Mauritius sugar mill) sequentially have negative values on sugarcane pol, mill extraction, boiling house recovery 11%, 5%, and 16%. Gap's acquisition value means that Ngadirejo sugar mill was below the benchmark (Mauritius sugar mill). Obtaining a gap can be used as a basis for improving Ngadirejo sugar mill to improve its performance and will have an impact on the production of yield value and white crystal sugar that generated. This is evident from the acquisition of the results of the yield prediction that Ngadirejo sugar mill generates regression coefficient value for some positive-valued variables. The result of the yield prediction is that Ngadirejo sugar mill yield has regression coefficient value for some positive value variable.

The prediction of bagasse pol value shows the regression coefficient value of the negative ME variables. The value of yield will affect the white crystal sugar that generated. Predicted yield used as a reference to know the amount of white crystal sugar production in Ngadirejo sugar mill. The prediction of white crystal sugar production is implemented in three scenarios. The first scenario is the average of actual conditions with 5 observations and the second and third scenarios are predictions with efficiency improvements using two observations. Based on scenario 2 and 3 showed that efficiency sugar mill increased toward production and productivity improvement sugar mill. Furthermore, the productivity measurement consists of the productivity of raw materials, sugar cane fields, sugar, energy, bagasse, and milling hours. The results of the research can be used as the basis for consideration as information to know the performance condition of the sugar factory. Therefore, more detailed development and assessment is needed about white crystal sugar production and bagasse associated with the use of other resources such as assumptions on the use of additives, unpredictable conditions (weather and strike machines), and labor skills in using the factory machinery.

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