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Techno-economic Analysis for the Production of Silica Particles from Agricultural Wastes

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Abstract

The purpose of this study was to evaluate the feasibility studies on the production of silica from agricultural wastes (*i.e.* rice husk, rice straw, bagasse, and corn cob) from engineering and economic perspectives. The engineering perspective was done by calculating stoichiometry, mass balance, and the preliminary plant design evaluation, whereas the economic perspective analysis was performed by calculating various economic parameters (*i.e.*, Gross Profit Margin, Internal Rate Return, Break Even Point, Payback Period, and Cumulative Net Present Value) under various conditions. The results from engineering perspective showed that the project is applicable even in the home-scale production. The project is potentially scaled up since it can be executed using commercially available and inexpensive equipment. Economic analysis showed that various agricultural wastes gave positive impacts on profitability, confirmed by the various economic evaluation parameters. Based on the evaluation from various agricultural wastes, rice husk is the best raw materials for gaining the highest interest, whereas corn cob is the worst. To confirm the analysis, various economic conditions under different raw material costs, utility costs, labor, and sales, as well as taxes, were added into the calculation, and they showed positive values for the potential production of silica particles. Although the evaluation confirmed for the excellent economic parameter values, further analysis of this project must be carried out to determine the uncertainty of conditions existing during the realistic project.

Keywords: Keywords: *economic perspective; engineering perspective; agricultural wastes; silica; economic parameter.*

1. Introduction

Silica is one of the most abundant materials in the earth's crust. This material is a type of inorganic compound that has unique characteristics such as having a porous structure, thermally stable, good mechanical properties, and low density, making it important for wide range of uses in industries, such as catalysts, adsorbents, biomedicine, composites, drug delivery systems, and electricity and daily life [1-5]. In industry, silica is usually obtained from the quartz sand mining process (as a raw material) through a conventional extraction process [4, 6-7], reforming it into chemical precursors such as tetraethylorthosilicate (TEOS), sodium silicate, and tetramethylor-thosilicate for being used for further production of silica-related products [8]. However, current production methods have met problems in the high production costs and not environmentally friendly [4, 8]. To against this circumstance, the agricultural wastes are potential to be used as a silica raw material since they have a high silica content. The chemical compositions in the agricultural wastes are presented in Tables 1 and 2. They are also harmless, inexpensive, and environmentally friendly [9]. The management and utilization of agricultural wastes also bring additional benefits for environmental preservation for the prospect in achieving renewable energy. Agricultural wastes are also sustainable at the global level, shown by the fact that they are widely produced continuously and annually they disposed in the world reaching millions tons per year. However, the progress in the use of them is still minimal [10-12], in which this can be found from the fact that they are only either burned in an open field or disposing to the ground. Yet, this practice is no longer allowed based on regulations on environmental issues [13]. Examples of the most abundant agricultural wastes are rice husk, rice straw, bagasse, and corn cob [8]. Several studies have reported the successful processes for gaining the silica component since silica is the main content in the agricultural wastes [8,14,16]. Although reports have been well-documented [8], shown the prospective insight for being utilized in industry, they presented in the lab-scale production only. In fact, utilization of agricultural wastes is expected to be an excellent alternative for substituting current silica raw materials that are scarce and expensive.

Table 1. Silica content in the ash of the agricultural wastes

Raw Material	Silica Content in Ash (%)	Reference
Rice Husk	90	[14]
	>90	[15]
	90-93	[16]
Rice Straw	75	[17]
	65	[18-19]
	74.6	[20]
Bagasse	92.5	[21]
	96	[22]
	89	[23]
	70	[24]
Corn Cob	90.6	[25]
	>60	[26-27]
	27	[21]
	52	[28]

Table 2. Silica composition in the agricultural wastes

Type of agricultural waste	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Silica (%)	Others components (%)	Total (%)	Reference
Corn Cob	42.5	32.5	15	10	0	100	[29]
Rice Husk	36	26	21	17	0	100	[30]
Rice straw	44	20	20	16	0	100	[31]
Sugarcane bagasse	38	27	22	9	4	100	[32]

Here, the objective of this study was to evaluate the production of silica from agricultural wastes from engineering and economic perspective. The engineering perspective was done by calculating stoichiometry, mass balance, and the preliminary plant design evaluation, whereas the economic perspective analysis was performed by calculating various economic parameters (*i.e.*, Gross Profit Margin, Internal Rate Return, Break Even Point, Payback Period, and Cumulative Net Present Value) under various conditions. The evaluation used and compared the effectiveness of the use of rice husk, rice straw, bagasse, and corn cob as models of agricultural wastes. The main method for extracting silica from these wastes is combination of burning process and acid-based extraction. Illustration for the process is presented in Figure 1. These combinations were selected because burning can create energy and the acid-basic extraction can be done using commercially available apparatuses. In the acid-basic extraction process, we selected the use of sodium hydroxide (NaOH) and phosphoric acid. NaOH is used due to its inexpensive raw chemical. Phosphoric acid is because this chemical can be directly neutralized and disposed to environment. This chemical also acts as fertilizer in environment.

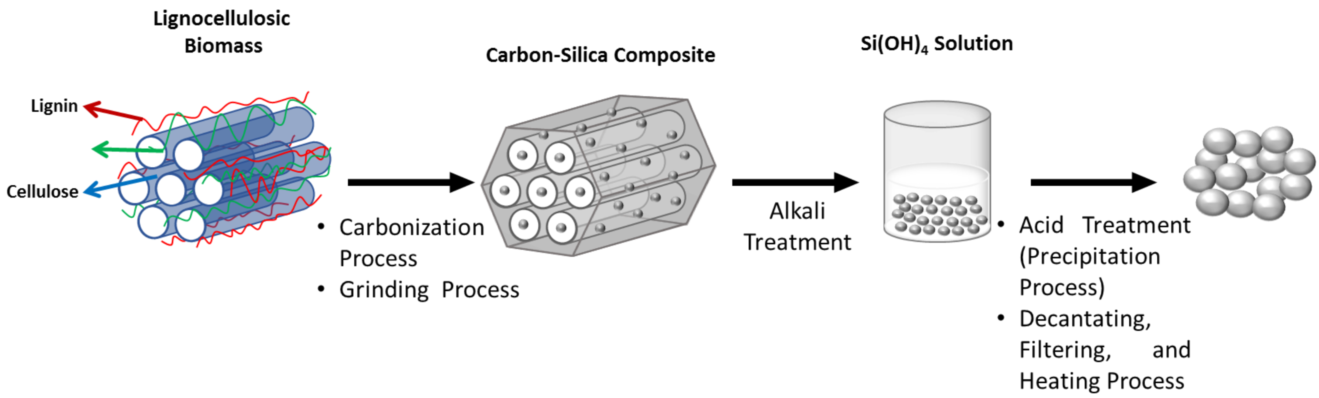

Figure 1. Illustration of steps for the extraction of silica from agricultural wastes

2. Fundamental Explanation in the Extraction of Silica from Agricultural Wastes

2.1. Burning Process

The burning process is conducted to get the advantages: creating energy from the combustion, removing most of the organic components, converting embeded silica in the cellulose structure into silicon oxide. Indeed, conducting the

burning process is also potential for enriching silica components in the product. The main reaction in the burning process is the conversion of biomass into volatile matters [33]. The biomass is composed mainly by cellulose ($(C_6H_{10}O_5)_n$), whereas the volatiles are CO, CO_2, H_2, CH_4, C_xH_y, CH_mO_n, and other compounds in traces. To be able to make model for the burning process, a description of chemical and physical phenomena involved is required. At a chemical level, burning process is a vast series of interlinked reactions. To avoid unnecessary complexity in the model, the reaction during the burning process may be simply described as a one-step first order reaction for the formation of primary product, while the inorganic components are only the transformation from its bending molecule from cellulose-related structure to its oxide structure (see Figure 1 in the illustration of inorganic components in the agricultural waste [34]). The simplification of the chemical reaction during the burning process is:

$(C_6H_{10}O_5)_n$ + oxygen → char + volatiles + energy

Inorganic components are embedded in the char. The volatile itself is defined

$$volatiles = \beta_1 gas + \beta_2 tar \quad (1)$$

$$gas = \delta_1 CO + \delta_2 CO_2 + \delta_3 C_x H_y + \delta_4 CH_4 + \delta_5 H_2 \quad (2)$$

In this study, all volatile components are neglected since the burning process allows the volatiles to further reactions with oxygen to produce carbon dioxide (CO_2) and water (H_2O). Thus, the mass analysis was done only by measuring the amount of char component. Since the reaction has no limitations in oxygen and the char formation did not inhibit the burning process, the rate for the formation of char is assumed to have first order of reaction.

$$\frac{dm_{char}}{dt} = C_D \cdot k \cdot m_{biomass} \quad (3)$$

where m_{char} is the amount of char, k is the constant, and $m_{biomass}$ is the amount of biomass added. C_D is the characteristic constant from the waste, which is a function of water content, porosity, silica content, and surface area (including particle size). This equation is applied for the mass balance calculation by multiplying with the flow of biomass added into the process. Regarding the k value, Arhenius approximation can be added.

$$k = A \cdot T \cdot \exp\left(\frac{E_A}{RT}\right) \quad (4)$$

where A, E_A, R, and T are the Arrhenius constant, the activation energy, the Boltzmann constant, and the temperature, respectively. The additional temperature in the equation is due to the exothermic condition, in which the burning process results in the additional heat from the oxidation of cellulose and volatiles. To simplify the equation, the derivation of the above equations are compared with the thermal gravity analysis under heating rate of 5°C/min and air flow of 200 mL/min [35], resulting

$$m_{biomass} = \gamma_1 \cdot \exp(-\gamma_2 \cdot T) \quad (5)$$

where γ_1 and γ_1 are the burning constants, corresponding to values of 125 and 0.0032, respectively. As explained above, additional advantages from the burning process is the creation of energy. Taken into account the release of energy from the combustion (q_p) as a direct function of internal energy (U), the equation can be delivered

$$\frac{dq_p}{dt} = n \cdot \frac{dU}{dt} \quad (6)$$

where η is the efficiency of the energy transfer from the burning system. The efficiency itself depends on the utilization of burning equipment and energy transfer tools such as heat exchanger. Adding the heat enthalpy (H_f) during the burning process under a specific condition (i.e. pressure (P) and temperature (T)), we can get

$$dH_f = dU + d(P \cdot V) \quad (7)$$

Thus, assuming that the energy was done in the constant pressure and temperature, the equation can be delivered as

$$q_p \approx C_{df} \cdot \Delta H_f \tag{8}$$

where C_{df} is the characteristic constant from the burning equipment for generating electricity.

2.2. Silica extraction process

This step is a method for purifying silicon dioxide (as it is formed from the burning process). The process is conducted using a basic solution to form silicic acid ($Si(OH)_4$), and subsequently it is added to acid solution at 70°C to form precipitated silicon dioxide (SiO_2) or silica. The reaction can be written as:

SiO_2 + acid → $Si(OH)_4$ *(chemical reaction is not equalized)*

and

$Si(OH)_4$ + base → SiO_2 *(chemical reaction is not equalized)*

The main parameters in the silica extraction process are the acid and basic solutions, in which this must be optimized to get optimum condition. The reaction rate can be approximated by

$$\frac{dm_{silica}}{dt} = k_0 m^p{}_{silica} + k_1 m^q{}_{basic} + k_2 m^r{}_{acid} \tag{9}$$

where m_{silica}, m_{basic}, and m_{acid} are the amount of silica, basic (NaOH), and acid (H_3PO_4), respectively. In addition, the amount of silica must be calculated carefully since it is embedded in the char.

3. Method

In this study, feasibility study was assessed from engineering and economics perspectives. We evaluated the process and compared several sources of agricultural wastes (*i.e.*, rice husk, rice straw, bagasse, and corn cob). The engineering perspective was used to evaluate the production of silica from agricultural wastes using combination of burning and acid-basic extraction processes [36]. The method was done by making simulation the process in the large-scale production using existing commercially available apparatuses. The process was then simulated based on mass balance involved during the process. In the economic evaluation, several assumptions were used based on all apparatus' specifications, prices for raw materials/chemicals, utility system, and equipment costs, in which these were adopted from online web stores, such as: Alibaba, Bukalapak, Tokopedia, etc. These data were then used and included in the calculations for economic feasibility analysis. The analysis was done by applying the calculation in the ideal and non-ideal conditions (by changing several variables: raw material prices, utilities, labor, and sales capacity). Then, the calculation used for the economic feasibility analysis was adopted from the literature [37-38]. Different from typical calculation of economic parameters [39], additional stoichiometry from the chemical reaction were added. The calculation is explained as follows:

- Gross Profit Margin (GPM) is gained through a reduction selling price and raw materials price.

$$GPM = \sum_{t=1}^{t} (S \cdot \eta - RM) PC \cdot Q \cdot t \tag{10}$$

where S, RM, and PC is the total sales, the total raw material, the production capacity, respectively. Q is the capacity of raw material inputted and applied in the process (kg/h), and t is the production time. η is the efficiency of the conversion, in which this is mainly depending on the chemical reaction in the burning and extraction processes.

- Cumulative Net Present Value (CNPV) is gained by totaling a Net Present Value (NPV) at a certain time from the start of the project. The NPV can be calculated by multiplying the cash flow with a discount factor:

$$NPV = \sum_{tr=1}^{tr} \left(\frac{R_t}{(1+i)^{tr}} \right) \tag{11}$$

where R_t is the net cash inflow subtracted by outflows during a single period of tr, i is the discount rate that could be earned in alternative investment, tr is the project time (in year), and Tr is the final year of the project..

- Internal Rate Return (IRR) was calculated using following equations:

$$NPV = \sum_{tr=1}^{tr} \frac{C_t}{(1+i)^{tr}} - C_o \quad (12)$$

where C_o and C_t are the total investment costs and the net cash inflow during the tr period, respectively. IRR is calculated from the value of r when the NPV is zero.

- Payback Period (PBP) predicts the length of time a project has to get its initial capital back. PBP is calculated when CNPV/TIC reaches zero.
- Break Event Point (BEP) is calculated by dividing fixed costs by profit.
- Profitability Index (PI) is estimated by dividing CNPV by sales and the total investment cost depending on the type of PI whether PI to sales or PI to investment.

4. Results

4.1. Engineering Perspective

In this study, silica particles from various sources of agricultural wastes (*i.e.*, rice husk, rice straw, bagasse, and corn cob) are fabricated through combination of burning and acid-based extraction methods, which are adopted from the literature [36-38]. The illustration process of silica fabrication is shown in Figure 2. The silica fabrication process is based on the bottom-up approach. The first step is the preparation and carbonization of agricultural wastes. Agricultural wastes are washed and soaked with water for 15 minutes to remove impurities attached to the agricultural wastes. After washing, they are dried (using an oven at 200°C for 2 hours), grinding (using a saw-milling process) and carbonized (using furnaces at 600°C for 4 hours). The second step is the silica extraction process. Carbonized agricultural wastes are then washed with water and centrifuged until the washing water no longer looks turbid (about 5 times washed). Then, the solution is put into a polymeric batch reactor and NaOH solution. The process using NaOH extracted is for 2 hours at temperature of 70°C to obtain silicic acid solution. The silicic acid solution is then washed by the centrifugation for 10 minutes at 11000 rpm to separate the silicate solution from the carbon residue. The third step is the nucleation process. The silicic acid solution extract is then added with phosphoric acid until the pH reaches 10 and white solids are formed. The white solid formed is then washed with methanol, centrifuged, and dried using an oven for 30 minutes at 50°C, and ground to obtain dry silica powder. The silica fabrication (as illustrated in Figure 2) was done through the following assumptions: (1). Raw materials were agricultural wastes (*i.e.*, rice husk, rice straw, bagasse, and corn cob), NaOH, and Phosphoric Acid, which are calculated and compared to literature [36-38]; (2). All raw materials were scaled up to 50,000 times from lab scale in the literature; (3). The conversion rates (for the gaining silica from agricultural waste ashes) are 91, 70, 85, and 60%, respectively, corresponding to the use of *i.e.*, rice husk, rice straw, bagasse, and corn cob [16, 40-41]; (4). Existence of losses during the process of transferring, drying, heating, and collecting products is 5%; (5). Assumptions for silica fabrication are taken based on 3 cycles in a day, with the composition of each raw material and yields of silica products on 1 cycle in a day are presented in Table 3.

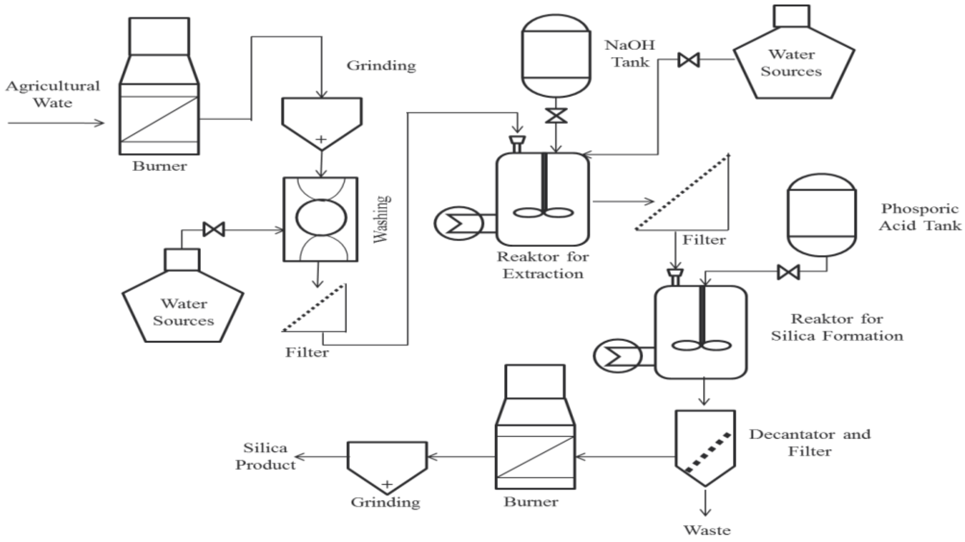

Figure 2. Ilustration Process of Silica Fabrication

Table 3. Composition of Raw Material and Silica Yield Product

Type of Agricultural Wastes	Amount of Agricultural Wastes (kg)	NaOH (kg)	Phosporic Acid (L)	Silica Yield (kg)
Rice Husk	2500	1800	38	400
Rice Straw	2500	2000	30	280
Bagasse	2500	4000	35	200
Corn Cob	2500	4500	25	150

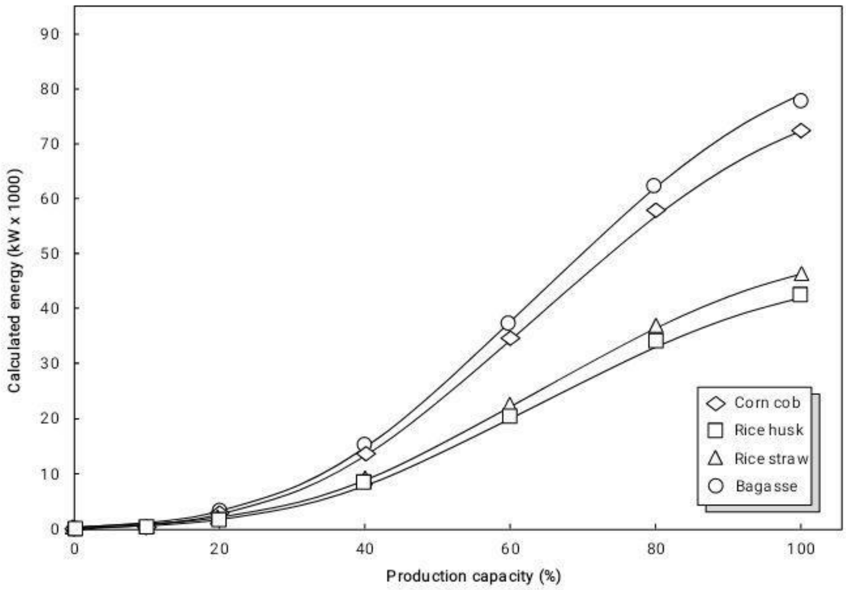

Figure 3. Production Capacity of agricultural waste on energy gained

Based on the assumptions, the silica produced during one year of production for *i.e.*, rice husk, rice straw, bagasse, and corn cob are 360,000; 352,000; 180,000; and 135,000 kg/year, respectively. In addition to the prospective use of

agricultural wastes (*i.e.*, rice husk, rice straw, bagasse, and corn cob) as the silica raw material, they produce energy from the conversion of organic biomass, giving a problem solver for against the dependence of fossil fuels. Energy calculation assumes the composition of waste are mostly cellulose (ΔH_f = -2828 kJ/mol; molecular weight = 162.1406) and silica (while other components are neglected), and the C_{df} value is 50%, the energy gained from the burning process is shown in Figure 3. The figure presents the availability of agricultural waste of the obtainment of energy. The more availability of agricultural waste correlates with the greater energy produced. Indeed, energy can be re-generated from the process itself and can be reused as an alternative energy used in this project, including reducing the project utility costs.

4.2. Economic Evaluation

Several assumptions were used to analyze the economic perspective of the silica project. i.e.: (a). Conversion from USD to Rupiah is 1 USD = Rp. 15.000; (b). All raw material prices and sales refer to online shopping web such as Alibaba, Bukalapak, Tokopedia, etc. The prices of raw materials such as NaOH and phosphoric acid are 0.26 USD/Kg and 2 USD/Liter, respectively. Meanwhile, agricultural waste can be obtained free of charge. The selling price of silica is 7.3 USD/kg; (c). Stoichiometry calculations are used to calculate all raw materials used during the silica fabrication process; (d). The discount rate and income tax are 15 and 10%, respectively; (e). Electric utility costs are 0.15 USD/kWh; (f). The water source is free of charge because the project is located near the river; (g). Silica production consists of 3 cycles per day. The time required for one cycle in the silica production is 2 hours; (h). Labor works for 300 days per year; (i). Lang Factor is used to analyze the project's total investment cost (TIC) (see Table 4); (j). The manufacturing cost is changeable and predicted from the beginning of the project.

Table 4. Lang Factor for Estimating Total Investment Cost

Component	**Factor**
Purchased Equipment	1
Piping	0.5
Electrical	0.1
Instrumentation	0.2
Utilities	0.5
Foundations	0.1
Insulations	0.06
Painting, fireprofing, safety	0.05
Yard Improvement	0.08
Environmental	0.2
Building	0.08
Land	0.5
Construction, engineering	0.6
Contractors fee	0.3
Contigency	0.2

The estimation of manufacturing cost is shown in Table 5; (k). Other supporting costs such as instrumentation, factory start-up, and electrical related components are neglected; (l). The project operated under a purchased land. Therefore,

the land is calculated as the initial cost of project construction which is then recovered after the project runs (at the end of the project); (m). Direct depreciation is used to calculate the depreciation value of the project; (n). The total wage is in a fixed value of 8 USD/day and the number of workers in this project is 50 people; and (o). The project operates for 20 years.

Table 5. Factor for estimating manufacturing cost

Component	Factor	
1. Labor related cost		
a. Payroll overhead	30%	of labor
b. Supervisory, misc. labor	25%	of labor
c. Laboratory charges	12%	of labor
2. Capital related cost		
a. Maintenance	6%	of (TPC-land)
b. Operating supplies	1.75%	of (TPC-land)
c. Environmental	2.25%	of (TPC-land)
d. Depreciation	5.00%	of (TPC-land)
e. Local taxes, insurance	4%	of (TPC-land)
f. Plant overhead cost	3%	of (TPC-land)
3. Sales related cost		
a. Packaging	1.00%	of sales
b. Administration	2.00%	of sales
c. Distribution and marketing	2%	of sales
d. Research and development	1%	of sales
e. Patents and royalties	1%	of sales

4.3. Ideal Condition

The engineering perspective shows that the project is easily operated, simply improved, and developed using technologies and apparatuses that are currently available and inexpensive equipment. In the economic evaluation, analysis in the ideal condition (shown in the 20-year CNPV curve in Figure 4) is very promising, confirmed by the PBP values that are relatively short (in only 2 years) to return all capital costs. Sorting the final CNPV values of various wastes from highest to lowest profits is sequentially for rice husk, rice straw, bagasse, and corn cob. CNPV relates to the number of product yield. The more product yields have direct correlations to the obtainment of more sales targets and profits by a project in certain periods [42]. Rice Husk source leads to getting the highest CNPV value since it has the highest silica content, making the process allowing the highest product. The CNPV curves from the corn cob is the lowest compared to others. This is because corn cob has the smallest content of silica, making the final product to have less amount of silica product. Besides CNPV analysis, overall economic feasibility parameter shows a positive value (see Table 6), confirming silica project is promising. The GPM value depends on the product capacity. The higher product capacity relates to the higher final CNPV value obtained. Based on the analysis of the profitability index (PI) based on PI to sales and PI to TIC, the most profitable silica projects are sequentially for rice husk, rice straw, bagasse, and corn cob. The higher of PI to sales and PI to TIC value replies the higher profitability. The BEP project values are almost the same for all cases. BEP is the point where income equals to capital spent (no loss or

profit is obtained). The greater project's profitability implies the better the BEP value of the project. The higher BEP value obtained correlates to the higher risk [42].

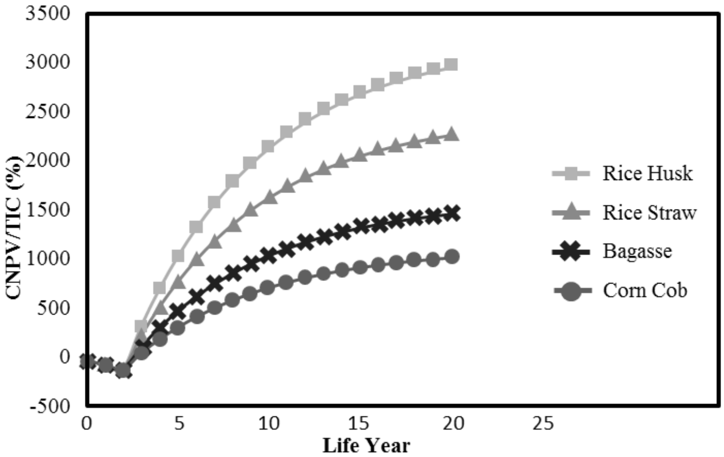

Figure 4. CNPV/TIC analysis of silica production

Table 6. Economic Parameter

Source	TIC (USD)	GPM/Year (USD)	PBP (Year)	IRR (%)	CNPV/TIC (USD)	PI to Sales (%)	PI to TIC (%)	BEP/year (Pack)
Rice Husk	430,300	3,687,100	4.54	2.83	3078	86.09	762.36	15,996
Rice Straw	430,300	2,902,600	4.54	2.43	2367	82.74	591.95	16,457
Bagasse	430,300	1,978,900	4.54	1.71	1380	80.47	393.17	16,720
Corn Cob	430,300	1,474,000	4.54	1.46	1080	74.22	283.31	17,801

4.4. Effect of Raw Materials and Sales

Figure 5 shows the effect of production factors (raw materials) on the GPM value of silica projects. In this study, since agricultural wastes are obtained free of charge, agricultural wastes are not included in the raw material calculation. Fluctuations in the price for raw materials are presented in Figures 5(a) and (b), corresponding to caustic soda and phosphoric acid, respectively. Fluctuations in prices significantly affect the GPM profits [42]. The analysis showed that all projects using various sources of wastes can still survive and operate until the price of raw materials reaches 200% of the estimated price. In the case of raw materials, caustic soda gave slightly higher impacts compared to the phosphoric acid. Assuming that the selling price of silica products (sales) is the same, the increases in prices of raw materials have a negative impact on profits [39].

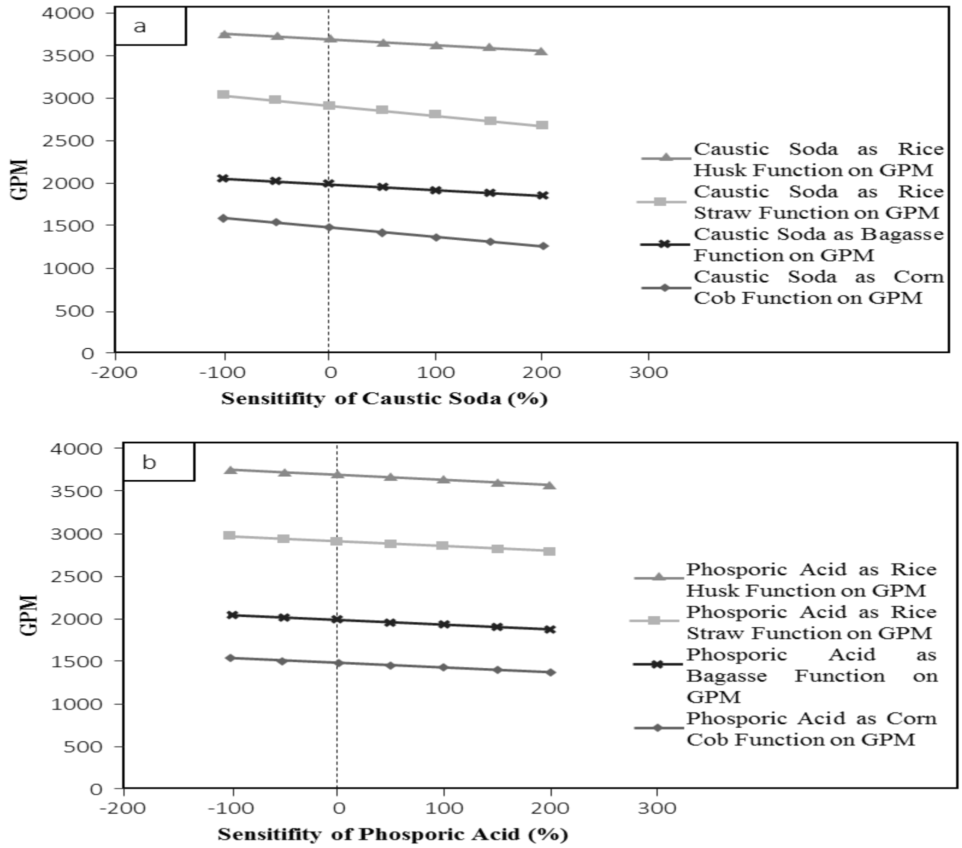

Figure 5. Effect of Caustic Soda (a) and Phosporic Acid (b) on GPM

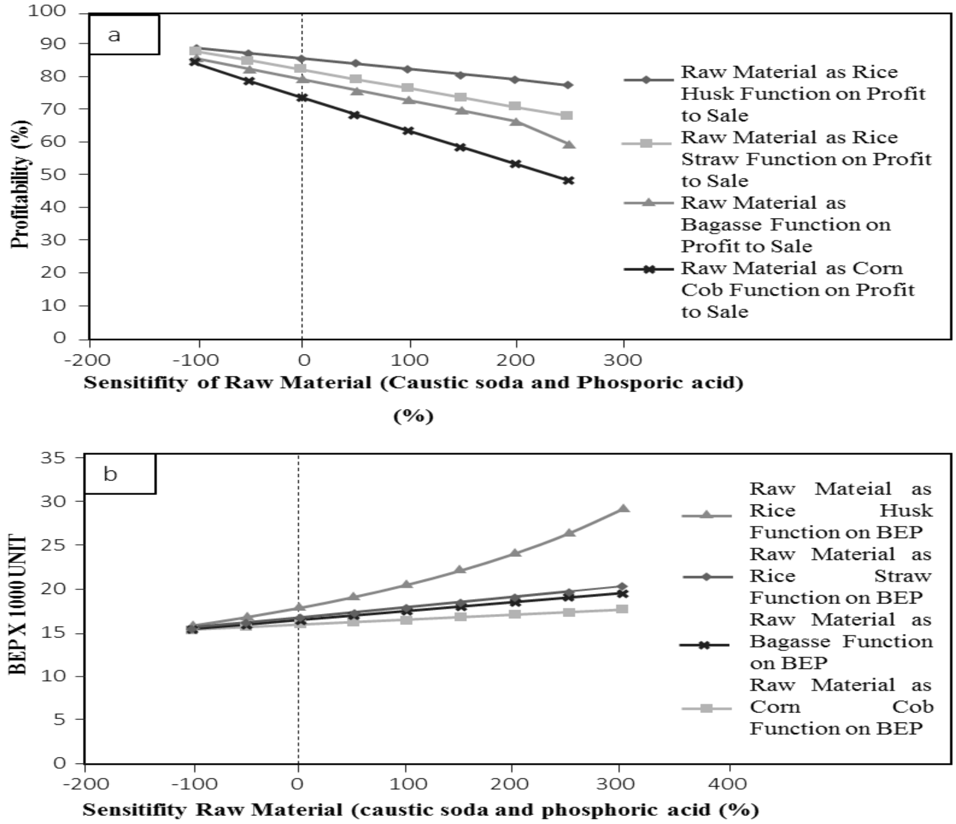

Figure 6. Effect of Cost of Raw Material on Profitability (a) and BEP (b)

Figure 6(a) shows analysis of sensitivity in the price change of raw material (caustic soda and phosphoric acid) on the profitability. In line with the GPM analysis, the increases in the raw material price of caustic soda and phosphoric acid has a direct impact to the continuity of the project (less profitability). The BEP analysis for the change in raw materials (*i.e.* caustic soda and phosphoric acid) is shown in Figure 6(b). The results showed that the higher prices of raw materials brought good influences on the obtainment of higher BEP values. Indeed, this informs that the costs of raw materials must be decreased as much as possible, in which this can be done by making agreements with the raw materials producers

4.5. Effect of Sales

Analysis of GPM in sales is presented in Figure 7(a). The results indicated that increases in selling prices had a positive impact on the profits [43]. All projects must be done using sales of higher than 50%. When the prices of product is less than 50% of the ideal sales, the project will be failure. Profitability analysis on sales is presented in Figures 7(b and c). The analysis showed that the higher sales allow more profits to be achieved. Based on GPM and profitability analysis results, in general, this study found that the project fails if the price of products is less than 50% of the estimated sales. The BEP analysis for the change in sales is shown in Figure 7(d). Increases in sales lead to the obtainment of smaller BEP value. Above results agree that higher sales will permit the higher profits from the project (see Figure 7(c)). However, too high prices of product does not give significant impacts on the project since it can cause decreases in the number of consumed products by market [44]. To improve the number of sold products, an agreement between producer and consumer is required, including understanding for absorbing the products. Indeed, this will correlate to the optimization of product price, especially in the situation when the increases in competition and limited demand development.

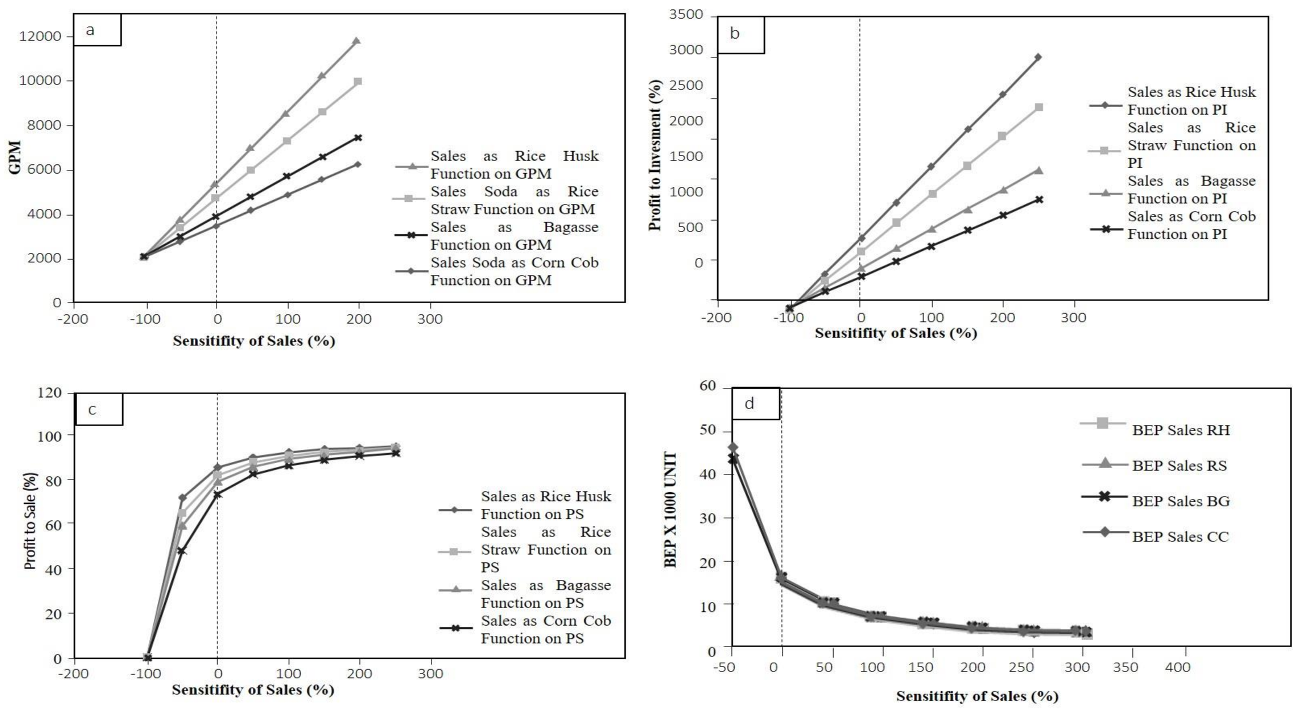

Figure 7. Effect of Sales on GPM (a), Profitability (b), and BEP (c) of the project

4.6. Effect of Utilities and Labor Cost

Results from the analysis of utilities and labor costs in the project are presented in Figures 8(a) and (b), respectively.

Different from raw materials and sales (as shown in Figures 5 and 6), utilities and labor have less impacts on the project profits, informing that the change in this parameter (up to 200%) is not a big issue in the sustainability of all projects (*i.e.*, rice husk, rice straw, bagasse, and corn cob).

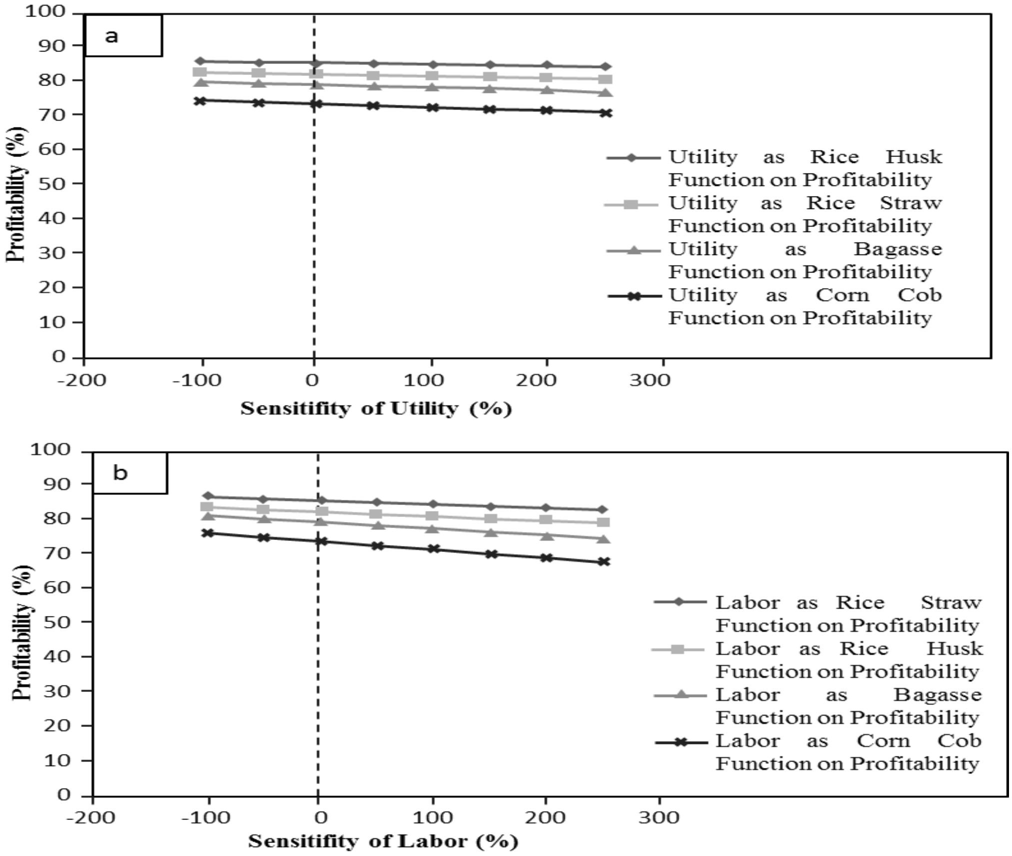

Figure 8. Effect of Utility (a) and Labor cost (b) on Profitability

4.7. Effect of Variable Costs

Variable costs are the combination of cost of raw materials, labor, utilities, and overhead costs. Variable costs are the largest costs that must be provided by the project. These costs must be used efficiently to achieve optimal profits [45]. Analysis of changes in variable costs to CNPV is shown in Figure 9. The change in the variable costs gave impacts on profits (shown by the change in the CNPV curves). Lower variable costs can produce maximum profits. The maximum value for the changes in the variable costs is 500% of the estimated values for all three projects (*i.e.*, rice husk, rice straw, and bagasse). As for silica projects from corn cob raw material, the maximum variable cost value is 400% of the estimated value. The impacts of the wastes influences on the consumption of raw material (*i.e.*, caustic soda and phosphoric acid) and variable costs used.

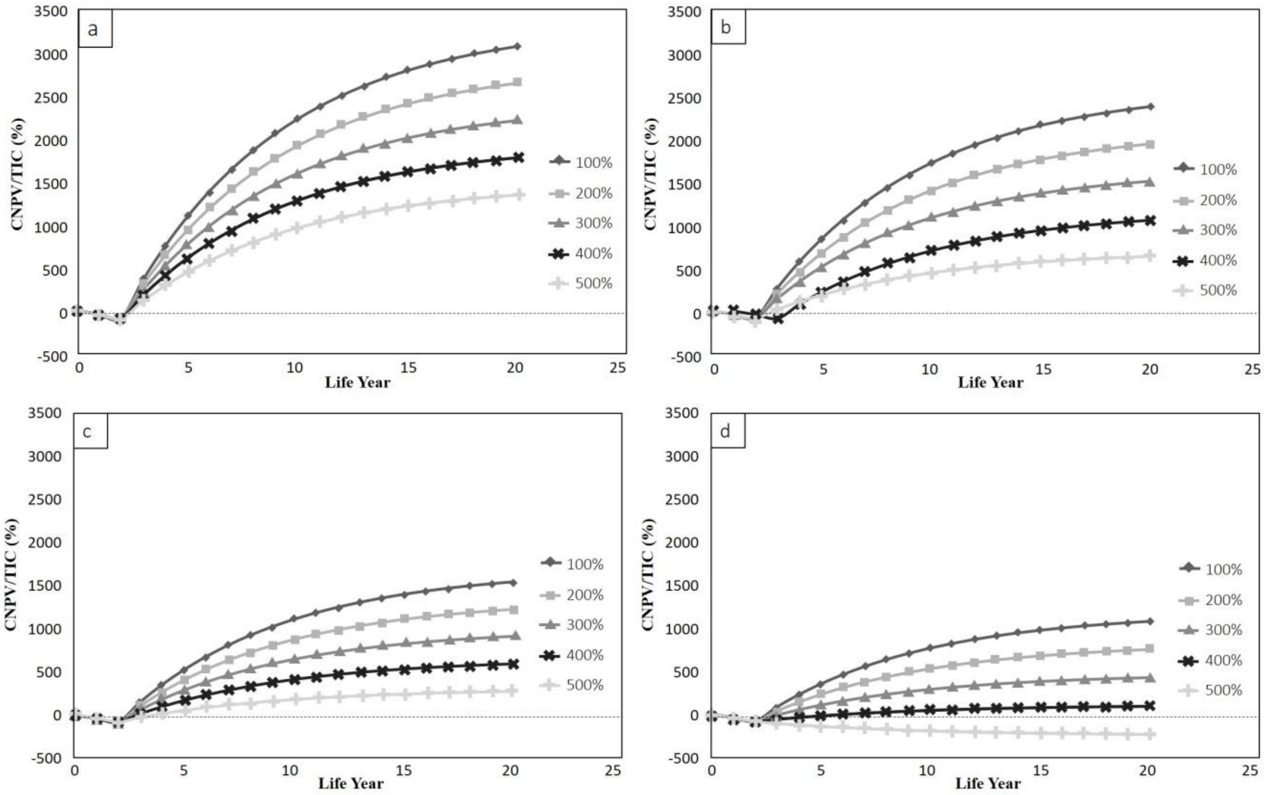

Figure 9. Variable cost analysis on silica project produced from rice husk (a); Rice Straw (b); Bagasse (c); and Corn Cob (d).

4.8. Effect of Production Capacity

Production capacity is the number of units produced and needed by a company to meet demands of products in the market [46]. Sometimes product capacity relates to the condition when there is a failure in the production process, such as limitations of raw materials and problems the production (such as equipment issue, product error, etc). Analysis of production capacity to the CNPV value is shown in Figure 10. The results showed that the minimum production capacity to maintain the project is 25%. If the production capacity does not reach the minimum capacity (less than 25%), the project suffer losses. Indeed, the higher production capacity has a correlation to the higher profit gained by the project, and it has impacts on the change of PBP [47].

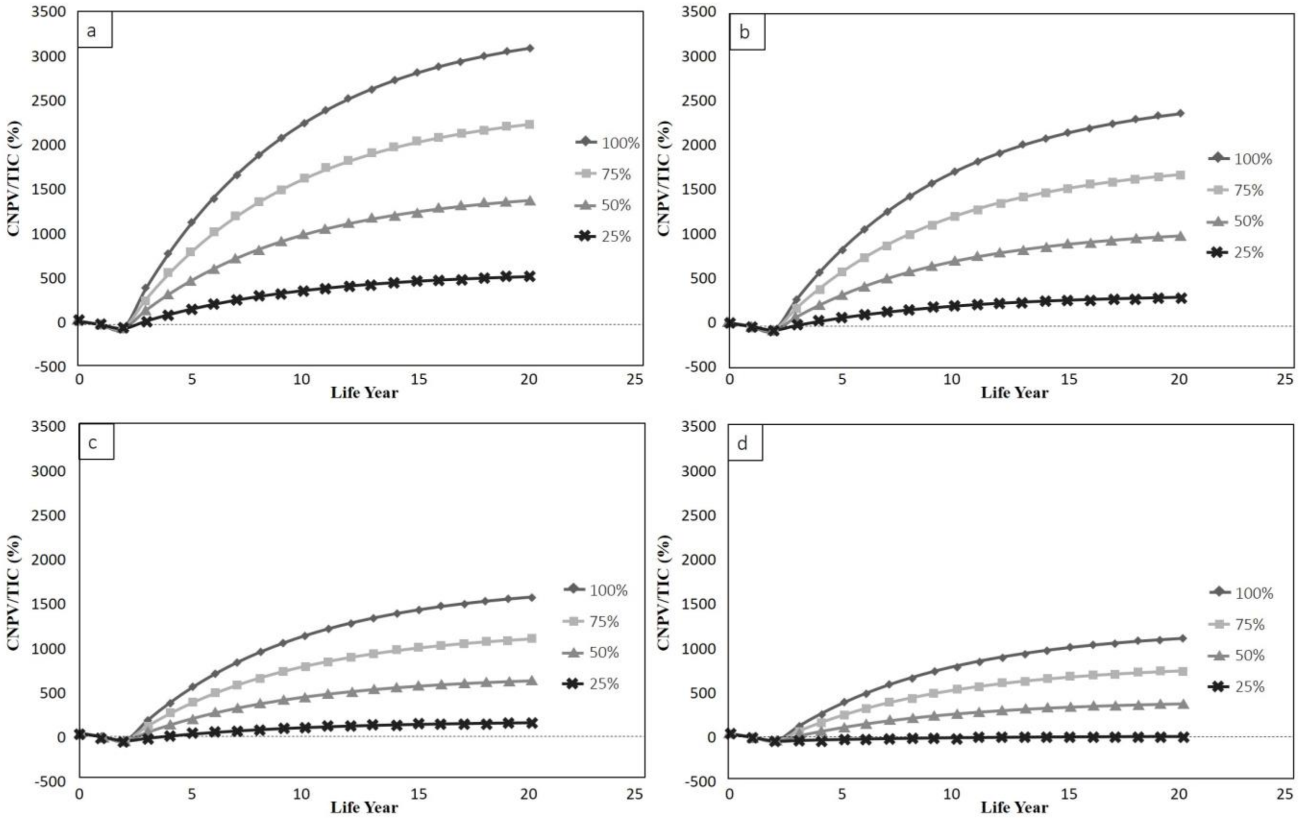

Figure 10. Production capacity analysis on silica project made from Rice Husk (a); Rice Straw (b); Bagasse (c); and Corn Cob (d).

4.9. Effect of External Condition

In addition to the internal factors such as raw materials, utilities, and labor, as well as production capacity, external factors must be considered since it gives influences on the successful project. External factors relate to the economic condition of a country where the project is established, including taxes and subsidiaries from the state imposing on companies [48]. To find out the effect of taxes imposed to companies, this study used speculative tax values that must be paid starting from 10 to 100% of the predictive value for the worst cases in Indonesia. Analysis of tax variations on the value of CNPV is shown in Figure 11. Analysis was done by comparing four types of the wastes (*i.e.*, Rice Husk (a); Rice Straw (b); Bagasse (c); and Corn Cob (d), corresponding to Figures 11(a), (b), (c), and (d), respectively). Similar trend in the CNPV curves were obtained for these types of wastes. In the year 0 to the second year, the taxes have not been charged to the company because this year is the project when is still under construction. The tax effect was investigated after two years of the established project. The analysis shows that the higher taxes imposed on a project result in the obtainment of smaller final CNPV value. The largest tax values to make the project still getting minimum profit is 75% of the predicted value. If the tax charged is more than 75%, then the project fails.

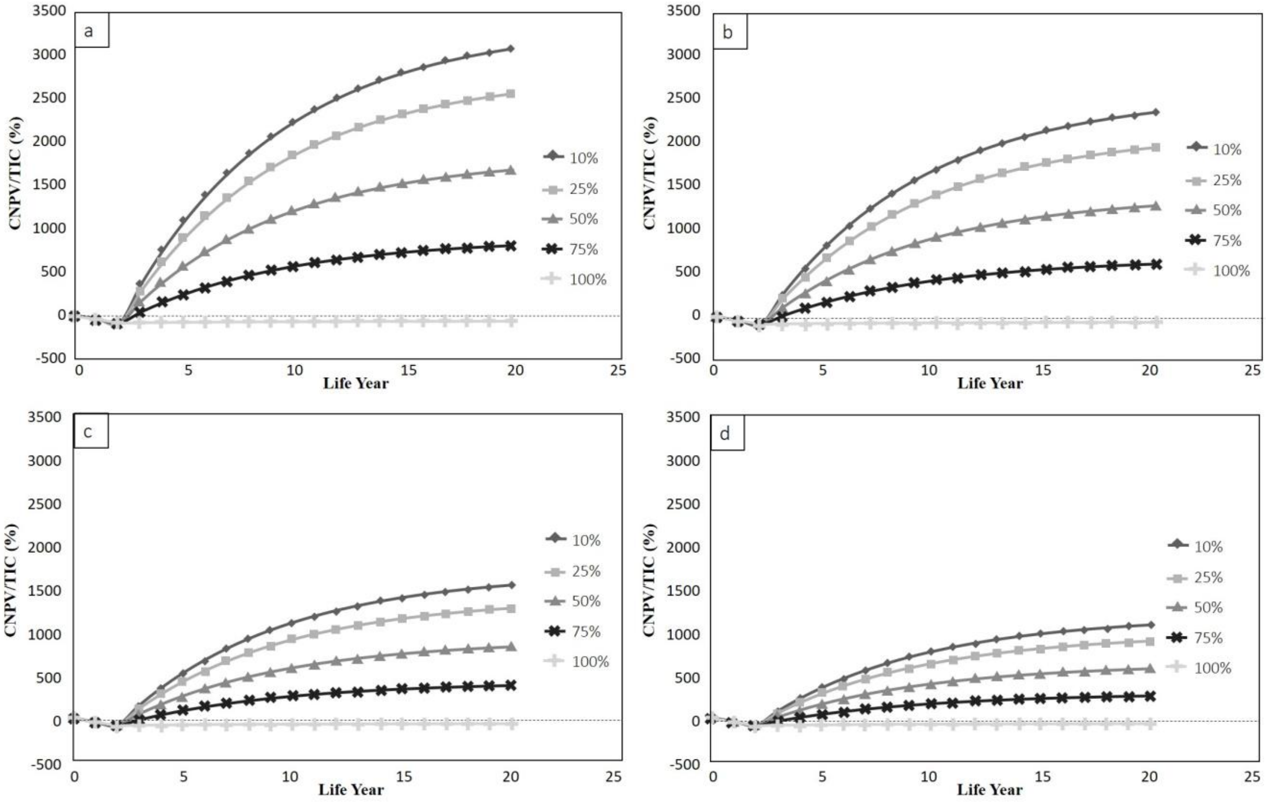

Figure 11. Tax Analysis on silica project made from rice husk (a); Rice Straw (b); Bagasse (c); and Corn Cob (d).

4.9. Engineering Perspective

The daily needs of silica projects and the number of yields produced per day for each type of agricultural waste (*i.e.*, rice husk, rice straw, bagasse, and corn cob) can be seen in Table 2. The results of the engineering analysis of silica projects with various raw materials originating from agricultural wastes are considered perspectives based on engineering evaluation and feasibility to scale-up process using available and inexpensive equipment. It confirmed by excellent TIC for each project. TIC values for each raw materials are shown in Table 5. The TIC value of the project is calculated using the Lang Factor.

4.10. Economic Perspective

Silica projects were analyzed based on ideal and non-ideal conditions. The results of the project analysis showed that the silica project from various agricultural wastes as raw materials shows promising results. However, when there is a change in economic conditions as shown in several cases the results of the analysis of non-ideal conditions of the project, it gets only minimal benefits. In detail, the economic conditions of the project are explained as follows: (1). The project is still profitable despite an increase in the price of production parameters such as raw materials (caustic soda and phosphoric acid), utilities, and labor of up to 200%. In this study, production parameters did not significantly affect the project profits; (2). Sales must be increased to get the maximum profit of a project. However, the selling price must also be optimized with the cost of production parameters. To maintain the project profit, the reduction in selling price must not be less than 25% for all cases; (3). The project is still profitable even though the tax charged is more than 75% for all projects. When the tax charged reaches 75%, the project is at a disadvantage and no loss condition. However, if the tax charged exceeds 75% the project fails; and (4). To find out the maximum profit of the project, we must look at the profitability analysis. The most profitable projects are silica projects sourced from rice

husk, rice straw, bagasse, and corn cob. The results of the economic analysis of silica projects with various agricultural wastes (i.e., rice husk, rice straw, and bagasse) showed promising results. This is shown from the positive values of economic parameters such as GPM, PBP, PI to sales, PI to TIC, and the final CNPV. PBP analysis shows that the project requires a relatively short in time to make a profit, which takes only 4 years to achieve the project's profit. In addition, indicators of the level of efficiency of the investment is confirmed by the IRR value. IRR of silica projects shows a small value (between 1.43 – 2.83%). The IRR value indicates that the proposed investment project should be rejected because it is not financially feasible. The final CNPV value for 20 years also shows a relatively small value. This provides unattractive perspective for investors for long-term investment, thus this project must be done in a short period. We also suggest that the project can be done under governmental project or Corporate Social Responsibility (CSR).

4. Conclusion

The results of the silica project analysis from an engineering perspective showed that the scale up of this project can be done using currently available and inexpensive tools. Analysis engineering showed that silica conversion from agricultural wastes was perspective and can be done under inexpensive investment. The economic perspective of silica projects shows the project is profitable but it is not attractive to industrial investors for long period. This project is a perspective solution to solve the problems of agricultural waste in agricultural countries. Whether this project is profitable or not, this project must still be built with additional financial support which is the social responsibility of the government or industry.

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