

**Techno-economic Analysis on the Production of CuO Nanowires by Simple Wet Chemical Method****Rahmadanti Widya Wardani, Asep Bayu Dani Nandiyanto\***

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**Abstract (English)**

The CuO nanowires prepared via this method are advantageous for industrial applications which require mass production and low thermal budget technique. Therefore this study aims to determine cost of production CuO Nanoparticles in the industry by simple wet chemical method. The economic evaluation method uses an analysis of several economic evaluation parameters such as Gross Profit Margin (GPM), Break Even Point (BEP), Cumulative Net Present Value (CNPV), Payback Period (PBP), and Profitability Index (PI). The results showed that on an industrial scale the amount of production a day is 1500 kg. The total production cost in one year is 570,253,527.75 USD, with total annual sales of 8,100,000,000.00 USD. Under ideal conditions the PBP analysis shows that the project will be profitable in year 3, and the PI analysis shows that the initial capital cost is recoverable from year 3. Based on the results of the economic analysis in this study, it can be concluded that the production of MgO nanoparticles is quite promising.

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Economic evaluation, hydrothermal, CuO, Nanowires.

**Abstrak (Indonesia)**

Kawat nano CuO yang dibuat dengan metode ini sangat menguntungkan untuk aplikasi industri yang membutuhkan produksi massal dan teknik dengan anggaran biaya yang rendah. Oleh karena itu penelitian ini bertujuan untuk menentukan biaya produksi CuO Nanopartikel di industri dengan metode kimia basah sederhana. Metode evaluasi ekonomi menggunakan analisis beberapa parameter evaluasi ekonomi seperti Gross Profit Margin (GPM), Break Even Point (BEP), Cumulative Net Present Value (CNPV), Payback Period (PBP), dan Profitability Index (PI). Hasil penelitian menunjukkan bahwa dalam skala industri jumlah produksi dalam sehari adalah 1500 kg. Total biaya produksi dalam satu tahun adalah Rp 570.253.527,75, dengan total penjualan per tahun sebesar Rp 8.100.000.000,00. Pada kondisi ideal, analisis PBP menunjukkan bahwa proyek akan menguntungkan pada tahun ke-3, dan analisis PI menunjukkan bahwa biaya modal awal dapat dipulihkan mulai tahun ke-3. Berdasarkan hasil analisis ekonomi pada penelitian ini, dapat disimpulkan bahwa produksi nanopartikel MgO cukup menjanjikan.

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CuO, Evaluasi ekonomi, Hidrotermal, Kawat nano.

**Background**

Since the discovery of carbon nanotubes, the synthesis of one-dimensional morphology such as nanowires and nanorods has gained much attention because this constitutes an important building block of nanodevices and integrated nanosystems [1-5]. Among the available transition metal oxides, such as Ni, Cu, Zn, and Fe, synthesis of CuO is an important topic of research. Cupric oxide, CuO, which is a p-type semiconductor [6,7] (indirect bandgap of 1.2 to 1.5 eV) has been widely exploited for diverse applications, such as an active electrode material for Li-ion batteries, field emission [FE] emitters, heterogeneous catalysts, gas sensors, and solar cells [8-13].

Moreover, the evidence of a spin-dependent quantum transport phenomenon in CuO nanowires was already reported [14]. Till now, many methods have been developed to synthesize CuO nanowires or nanorods, such as thermal oxidation of copper foil, hydrothermal route, aqueous reaction, vapor-liquid-solid synthesis, solution-liquid-solid synthesis, laser ablation, arc discharge, precursor thermal decomposition, electron beam lithography, and template-assisted synthesis [5,15-19]. However, all these methods either require high temperatures, sophisticated instrumentation, inert atmosphere, or long reaction time. The difference between the method in this manuscript and the aqueous reaction referred earlier is the starting precursor material used and the stabilizer. In our case, the precursor used is copper acetate, while in the aqueous reaction, copper chloride. We used the organic molecule thioglycerol [TG] as stabilizer, while no stabilizer was used in the latter case. Moreover, until now, few reports are available in literature for the synthesis of CuO nanowires using the organic molecule TG. Therefore, in the present study, a systematic effort has been made to synthesize CuO nanowires by a simple and inexpensive wet chemical method using copper acetate and NaOH as the precursor material in the presence of organic molecule TG. The possible formation mechanism of CuO nanowires via this chemical method is also discussed.

## Method

### 1. Synthesis CuO Nanowires

All the reagents were of analytical grade and were used without further purification. Copper acetate ( $\text{Cu}(\text{CH}_3\text{COO})_2$ ) and sodium hydroxide [NaOH] were used as precursors in the present experiment. Two separate solutions, copper acetate (0.5 M) in deionized [DI] water and NaOH (5 M) in DI water, were prepared. Aqueous copper acetate and aqueous NaOH solutions were referred to as solution A and solution B, respectively. Stirring is continued until the respective metal salts are completely dissolved in DI water. Later 1  $\mu\text{L}$  of TG is added to solution A, and the solution is stirred for a few minutes. Solution B is then added to the reaction mixture, and water is immediately added. Further stirring continued for a few minutes. Centrifugation is done to collect the precipitate. Washing of the precipitate is carried out using the DI water for five to six times. Finally, the collected precipitate is dried overnight at  $35^\circ\text{C}$ .

Schematic production process of CuO nanowires shown in the Fig. 1.

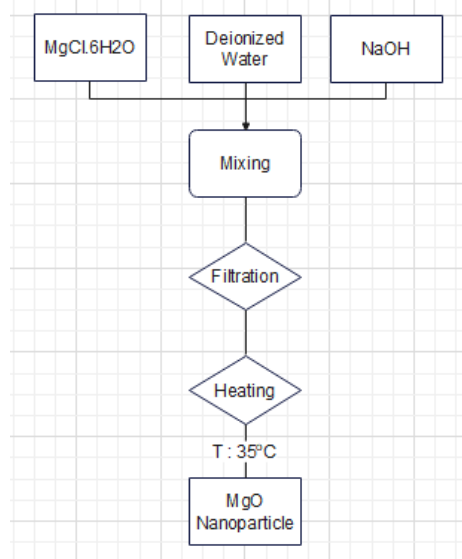


Fig. 1. Schematic process on the production of CuO nanowires

## 2. Economic Evaluation

On the economic-evaluation study, an analysis of the prices of equipment, utilities and raw materials available for the manufacture of magnesium oxide nanoparticles was carried out on the Alibaba and Tokopedia online shopping site. Then the data is calculated using Microsoft Excel with several parameters such as GPM, IRR, PBP, CNPV, BEP, and PI from various cost variables. Calculations were made based on literature (Nandiyanto, A.B.D., 2018), (Ragadhita, R., *et al.* 2019), (Nassar, M.Y., *et al.* 2017), (Garrett, D.E., 2012). To get the results of this study, calculations were carried out using several formulas such as:

- GPM is profit calculated from the ratio of gross sales to net sales.
- CNPV is a value to predict production conditions as a function in one year. The CNPV value is calculated from the NPV at a certain time. NVP is the cash value of the business, including expenses and revenue.
- IRR is a method that calculates the interest rate of an investment and then equates it with the current investment value based on future net cash calculations. The purpose of calculating the IRR is to determine the level of efficiency of an investment.
- PBP is calculated to determine the length of time needed to return capital through profits. PBP is calculated when the CNPV reaches zero.
- BEP is the point where income equals capital. There is no gain or loss when the BEP is reached. BEP is known to divide capital by profits.
- PI is the estimated result that is known when dividing CNPV by sales (PI for sales) or total cost of investment (PI required for investment).

## Result and Discussion

### 1. Engineering Perspective

There are several assumptions based the illustration of production MgO nanoparticle shown at Fig. 2.

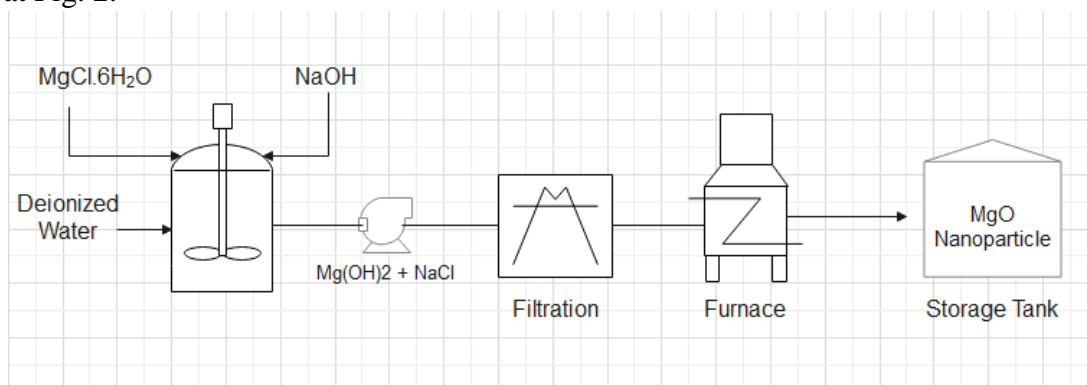


Fig. 2. PFD synthesis of CuO nanowires

There are several assumptions used to ensure economic analysis. This assumption is needed to analyze and predict several possibilities that may occur during the project. These assumptions are :

1. All analyzes use USD (1 USD = 15,628 rupiah);

2. Based on commercially available prices, the prices for Magnesium Chloride Hexahydrate ( $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ) and Sodium Hydroxide ( $\text{NaOH}$ ) are 63.99 USD/kg and 38.39 USD/kg.
3. The cost of water as a solvent is assumed to be 0 USD because the project is close to a water source
4. All materials are estimated based on stoichiometric calculations;
5. The selling price of MgO Nanoparticles is 60 USD/kg;
6. Total Investment Cost (TIC) is calculated based on the Lang Factor (Garret, 2012);
7. Depreciation is estimated using direct calculations (Garret, 2012);
8. One cycle of the process of making magnesium oxide nanoparticles takes 6 hours;
9. A project year is 288 days (and the remaining days are used for cleaning and organizing processes);
10. To simplify utilities, utility units can be broken down and converted into electricity units, such as kWh. Then, the unit of electricity is converted to charge. The unit of electricity (kWh) is multiplied by the cost of electricity. The assumed annual utility costs are 26,411 USD/kWh;
11. The total salary/labor is assumed to be 40 people with a salary per person of 6 USD/day;
12. The discount rate is 15% per annum while the income tax is 10% per annum;
13. The operating period of the project is 10 years.

Economic evaluation is carried out to test the feasibility of the project. Economic evaluation is done by varying the value of raw materials, utilities, sales, labor, under several conditions. The variations applied to materials, utilities, sales, and labor are 100, 125, 150, 175, 200%.

## 2. Economic Evaluation

### Ideal Condition

In economic evaluation, it is necessary to have ideal conditions, so that it can be used as a benchmark for a project. Fig. 3 shows ideal conditions by analyzing the relationship between CNPV/TIC and lifetime (years). The curve shows a negative CNPV/TIC value. The lowest CNPV/TIC value occurred in the second year, namely -0.8452%. However, after year 3 onwards up to year 10 it can be said to be profitable because CNPV/TIC continues to increase. In the 3rd year the income increases and reaches the Payback Period (PBP). CNPV/TIV negative from year 1 and year 2 (Table 1). This condition is referred to as the payback point, and the increase shown on the chart is called the Payback Period (PBP). The PBP was achieved in only a short time and the income earned tends to increase until the 10th year. This indicates that the MgO nanoparticle production project quite promising.

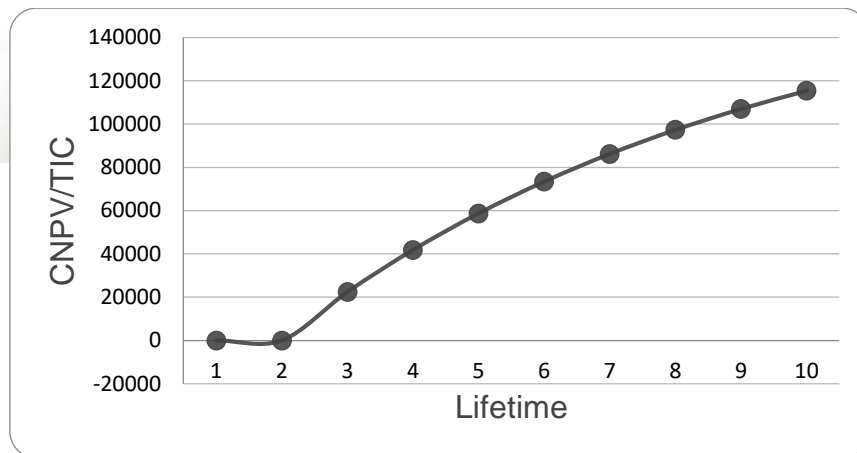


Fig. 3. Ideal conditions for CNPV/TIC to a lifet ime (year)

Table 1. Annual CNPV/TIC values in ideal conditions

CNPV/TIC	Year
0	0
-0.409351928	1
-0.845204551	2
22358.7406415372	3
41801.8587685706	4
58708.9180094691	5
73410.7086537287	6
86194.8744313458	7
97311.5403249259	8
106978.2063193430	9
115384.0028362280	10

### Variable Cost Changes

The economic evaluation analysis in this study also pays attention to several variable cost variation factors, such as raw materials, utilities, and labor salaries that can affect the success of a project. Fig. 4 shows a graph of the relationship between CNPV/TIC and variations in raw material prices. The y axis is CNPV/TIC (%), and the x axis is Year. The ideal raw material price is 100%. Analysis of raw material variations is carried out by increasing the percentage price of these raw materials

by 25% from ideal conditions. So, the variations of raw materials used are 100, 125, and 150, 175, 200%. The CNPV/TIC value is the same in the initial conditions of the project (0-2 years) because the project is still in the development stage. Variations in raw materials begin to affect CNPV/TIC values after the 3rd year the project is running. A decrease in raw materials will increase profits, and a company's profits will decrease when prices rise. CNPV/TIC values in the 10th year for variations of raw materials 100, 125, and 150, 175, 200%. The following is the CNPV/TIC at ten years for variations in raw materials which can be seen in Fig. 4 below.

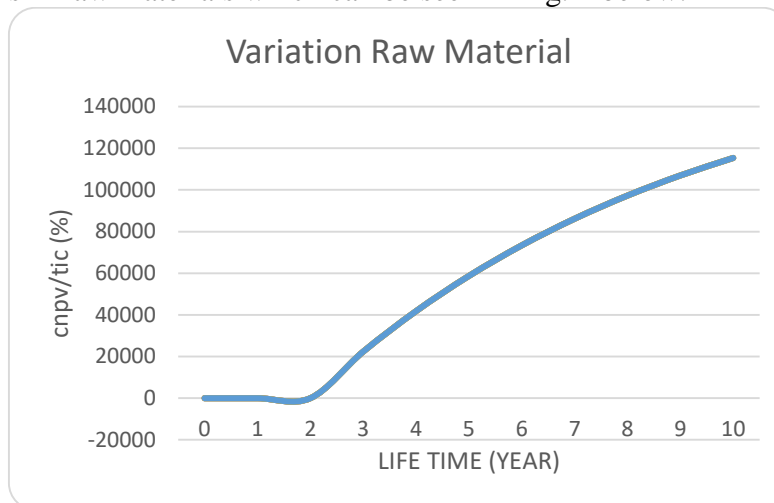


Fig. 4. CNPV/TIC with raw material variation against year

The y-axis is CNPV/TIC (%), and the x-axis is the year. The analysis is carried out by increasing the percentage of utility prices by 25% from the ideal price. The ideal utility value is 100%. The variations in utility prices are 100, 125, and 150, 175, 200%. The CNPV/TIC value in the first two years of the project is the same because the project is still in the development stage. The effect of utility on the value of CNPV/TIC can be seen after three years of the project's journey. Based on the results of the graph Fig. 5 it can be seen that there is no significant effect on variations in utility prices. This can be caused by the relatively low price of utilities so that the variations carried out relatively do not significantly affect the value of CNPV/TIC on variations in utility prices. However, this project can still run and generate profits. PBP results of utility variations of 100, 125, and 150, 175, 200% can be obtained in the 3rd year. The following is the CNPV/TIC (%) for utility variations which can be seen in Fig. 5 below.

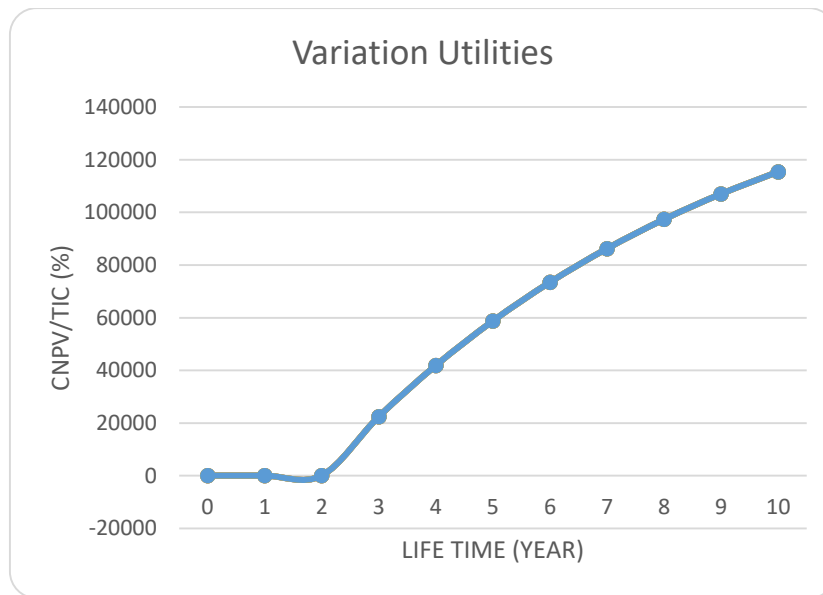


Fig. 5. CNPV/TIC with utilities variation against year

Fig. 6 shows a graph of the relationship between CNPV/TIC and the variation of operating labor. The y-axis is CNPV/TIC (%), and the x-axis is the year. The analysis is carried out by increasing the percentage of labor salaries by 25% from ideal conditions. The ideal labor salary on the chart is 100%. The variations in labor salaries are 100, 125, and 150,175, 200%. From year 0 to year 2 the CNPV/TIC value is the same because the project is still in the development stage. The effect of variations on labor salaries will be seen starting in the 3rd year the project is running. With the greater the salary of labor, the profit will decrease and vice versa. PBP values for each employee salary variation of 100, 125, and 150, 175, 200% are achieved in the 3rd year. The following is the CNPV/TIC (%) for the year for variations in employee salaries which can be seen in Fig. 6 below.

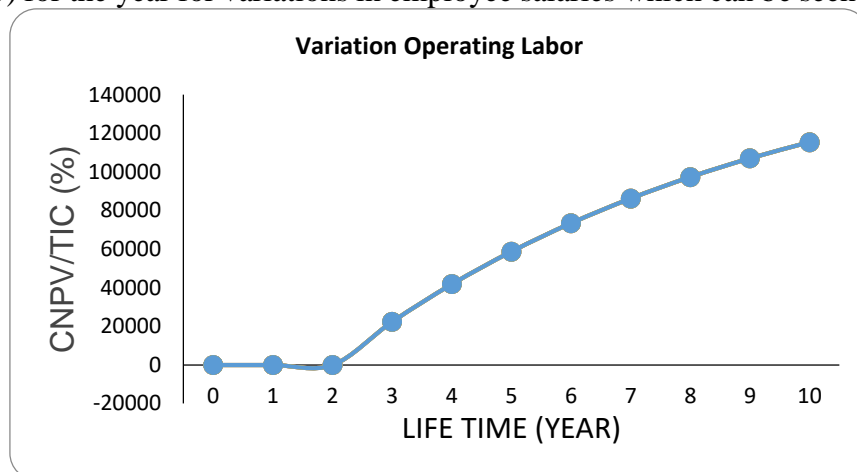


Fig. 6. CNPV/TIC with operating labor variation against year

### Change in Sales

Fig. 7 shows a graph of CNPV/TIC in life time with variations of sales for 10 years. Variations of sales made are 100, 125, 150, 175, and 200%. The graph shows that at first to second years there is no difference in sales variations because the project is still in the development stage. The effect

of sales on CNPV can be seen in the third year where the graph shows that the greater the sales value, the more profit will be obtained. However, if there are conditions that cause product sales to decline, the project's profits will fall from ideal conditions.

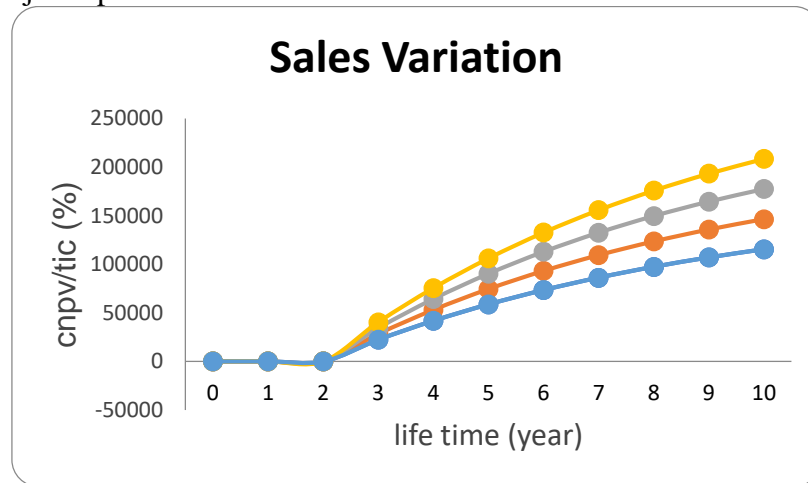


Fig. 7. CNPV/TIC against life time (year) for sales variations

## Conclusion

Based on the results of the economic analysis in this study, it can be concluded that the production of CuO nanowires by hydrothermal method is quite promising. This project simulation can be said to compete with the standard PBP capital market because the investment payback period is relatively short (in the third year the project is running). This project is also feasible to carry out with the anticipation of losses that will occur due to changes in selling prices and raw material prices.

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