Feasibility Study to Develop Production of Active Ingredients $NaNi_{0,5}Ti_{0,5}O_2$ Sodium Cathode : A Case Study From Salt in Java Island

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Abstract

The use of lithium in non-renewable energy storage cathodes is possible to run out someday. Therefore, an alternative is sought to replace it, namely the manufacture of cathodes made from sodium sea salt as raw material. This has been proven because there are many patents and research conducted by researchers. To carry out production, a cost analysis related to the process must be carried out. This study aims to calculate the cost components, especially the Cost of Production in the experiment of making cathode active ingredients made from salt. The method used in this research is using primary and secondary data. The results obtained in this study are the Cost of Production of the cathode active ingredient products made from sodium is Rp. 132,677 per 100 grams and the selling price is Rp. 150,000 per 100 grams. This price is very much cheaper compared to the price of active cathode materials made from lithium which is Rp. 250,000 per 100 grams. Apart from being cheaper, the Cost of Production is also easy to obtain, the production of active cathode materials also has a profitable economic value so that this study is appropriate to continue regarding scale up on a factory scale.

Keywords
Cathode, Energy Storage, Renewable, and Salt, Sodium.

1. Introduction
Energy demand in the future is predicted to increase along with the increasing human population in the world. However, this will have an impact on the need for electric fuel to be used. This is evidenced by the consumption of lithium in 2008 amounting to 21,280 tons and will continue to increase with a growth of 5% per year Hwang et al (2017). Lithium production and distribution will develop in certain regions such as Australia, South America, China, and the United States. In addition, the world energy storage market will reach $ 13.13 billion by 2023 from global data forecasts Liu et al (2020). Sodium is a material that is very satisfying to lithium which is used as a raw material for making cathodes so that it is more specific as a raw material for making cathodes Wang et al (2020).

With this potential, there must be development on an industrial scale so the active cathode material can be produced more and can provide benefits to life, and also the environment. With this development, the community will be more aware of the environment. This will be a positive inspiration for the global community so electricity generation with renewable energy from water, wind, sun, and so on will be intensified because the power from these energies will be more stable if the energy is stored in batteries so as they will not damage electronic components.

Furthermore, a feasibility evaluation is carried out to anticipate planning errors and minimize the risk of loss. A feasibility study is research on the establishment or expansion of a project to determine whether or not the project is feasible and profitable. The main step in determining the estimated cost in the manufacture of ion batteries is to make a bill of materials first. Bill of materials is needed to determine the components that will be used in research Sutopo et al (2016). If a scale-up is carried out on a factory scale, using 4 stakeholders that is salt farmers, salt storage terminals, cathode factories, and the distribution center Suryati et al (2020). The supply chain model that considers government investment schemes to improve the product distribution system can use multi-objective optimization, this model has the advantage of improving the relationship between buyers and suppliers through government incentives to improve the distribution system of materials and products Lupita (2017).

1.1 Objectives
The purpose of this research is to calculate the cost components, especially the Cost of Production in the experiment of making cathode active ingredients made from salt.

2. Literature Review
Salt is an ingredient that can be produced in abundance Yabuuchi (2012) & Barpanda (2014). Oxide-coated sodium is a promising cathode due to its excellent electrochemical properties, besides that this material also has low toxicity making it safer for the environment. Sodium are reliable competitor in the battery field due to its abundant availability, easy availability, and competitive electrochemical properties Barpanda (2016). The sodium oxide layer is usually marked with their respective names such as O3, P2, P3, etc. In O3 Han (2015). the sodium content is high with a greater diffusion content than P2 and P3 Bianchini et al (2018). Sodium batteries have interesting opportunities as high energy density, low cost, and relatively efficient storage of electrochemical energy Song et al (2017).

One alternative for LIB (Lithium Ion Battery) is a SIB (sodium Ion battery). SIB has recently attracted attention as a promising commercial alternative to scale energy storage systems due to its relatively high abundance of sodium resources in the earth's crust and seawater and its relatively low production costs Hwang et al (2017). In addition, sodium is in the same group as lithium in the periodic table of elements and has similar Physico-chemical properties Yabuuchi (2012). that the mechanism of action of SIB is very similar to LIB and to make sodium cathode active ingredient precursors the most appropriate process is to use the Solvay process Nyamiati et al (2019). The performance of sodium ion storage includes a high capacity of 250 mAh/ g and has a long life cycle up to 9000 cycles so that this can accelerate the application of sodium-ion batteries to be used as energy storage Zhang W et al (2019). When integrated N, S, and O are abundant as a redox center, the NS-GNS electrode has a capacity of 400 mAh / g and has a cycle of up to 10,000 Ma Y et al (2018). When compared with 3 types of battery material, Lithium Cobalt Oxide (LCO) which has a cycle life of 500-1000, Lithium Iron Phosphate (LFP) cycle life of 1000-2000, and Lithium Nickel Manganese (NMC) life Cycle of 1000-2000 Sholichah et al (2020) Sodium batteries are still far superior because their cycle life is longer than lithium. Market testing is a process to identify the size of the market owned by sodium or lithium batteries so that they can compete in the market with competitors Kurniyati et al (2016)

Batteries have several types including primary or non-rechargeable batteries (batteries that cannot be recharged), and batteries that can be refilled. This non-rechargeable battery is usually used in emergency conditions, such as medical equipment, electronic media such as watches, wall clocks, and so on. Meanwhile, rechargeable batteries are often used for transportation purposes such as electric motors, cellphones, and so on Deng et al (2020).

The components of a sodium battery consist of an anode, cathode, electrolyte, and separator. The electrode is an important component that has an important effect on battery capacity Barpanda (2015). Several studies on sodium battery cathodes have been carried out, including cathodes based on sulfide, fluoride, phosphate, and sulfate and oxides. Oxide-based cathodes have the potential to be developed because they have a more stable structure. One of them is $NaNi_{0.5}Ti_{0.5}O_2$, the complete process can be seen in figure 1, which is an oxide cathode coated with a transition metal of nickel and titanium.

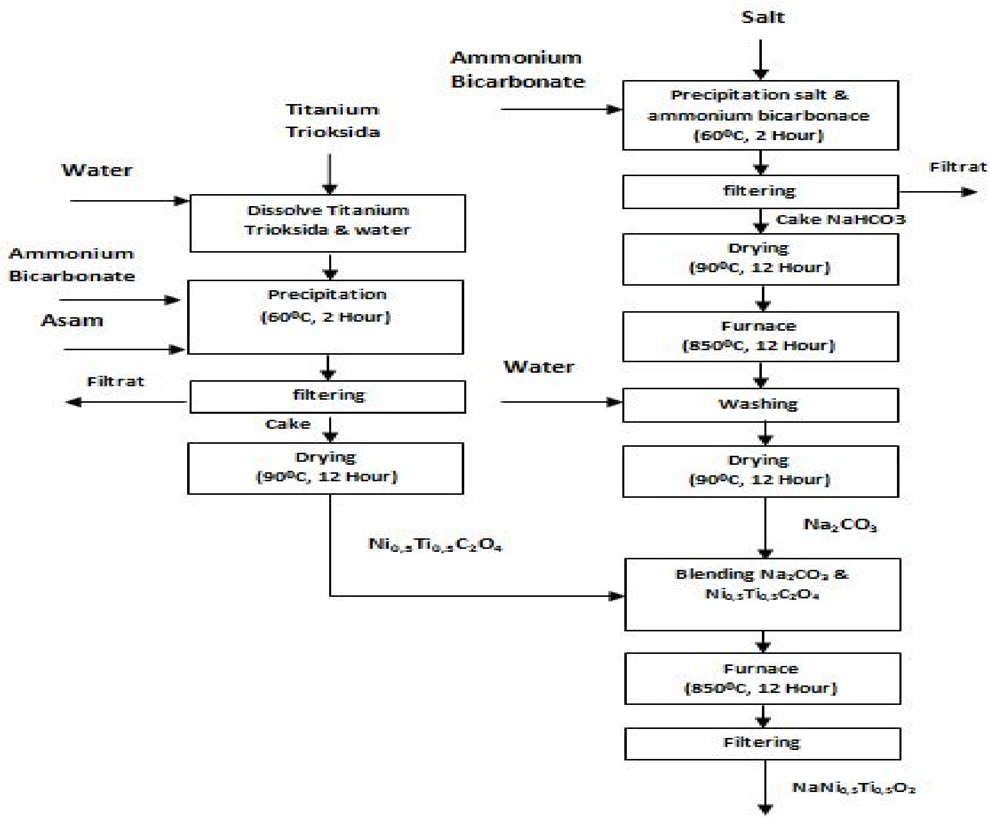

Figure 1. Flowchart Process (Source : Hwang, 2015)

Based on the process described in Figure 1, it can be seen that some of the main tools needed to be owned include a high pressure hydrothermal reactor, an atmospheric muffle furnace, a ball mill, a filter press plate and frame, and an oven. machine and specifications are shown in table 1.

Table 1. Machine & Specification

Machine	Name	Spesification	Source
	Filter press and frame	Capacity 0,6 cu.ft Mild steel construction Centre feed with 4 corner dischare Hydraulic pum, pressure gauge and air blow header with valves	https://www.mwwatermark.com/plate-frame-vs-recessed-chamber-filter-press/
	Laboratory Drying Oven	Temperature Range : 5℃ to 300 ℃ Internal Capacity : 53 Litres Power : 1,4 KW Voltage : 230 V Weight : 57 Kg	https://www.stanhope-seta.co.uk/product/laboratory-oven/

	Atmospheric Muffle Furnace	Chamber Dimension : 200*200*200 mm Max Temperature : 1650 ℃ Rated Temperature : 1500 ℃ Temperature Uniform : ±5℃ Water Cooling Capacity : 50W/℃ Capacity : 9 L Cooling Water Speed : 15 L/ minute	https://cykylabequipment.en.made-in-china.com/product/QBGmSlkUqeRp/China-Atmosphere-Muffle-Furnace-Used-for-Material-Synthesis-Under-Controlled-Inert-Gas-Atmosphere.html
	High Pressure Hydrothermal Reactor	Range of spindle : 1-1450 rpm Weight : 1000 Kg Voltage : 220-480 V Power : 15 kW Frame Speed : 0-75 rpm Emulsifier Speed : 0-1500 rpm	https://www.alibaba.com/product-detail/Stainless-Steel-Hydrothermal-Synthesis-Reactor-Liquid_1600209114652.html
	Ball Mill	Weight : 15 Kg Material : Stainless Steel Capacity 2 Kg Voltage : 200 V Motor Power : ¼ H.P Shell Rotation Speed : 80 RPM	https://www.indiamart.com/proddetail/lab-ball-mill-19529457991.html

3. Methods

In this study, the method used was to collect primary and secondary data. After that, an assessment of the feasibility of the cathode active ingredient manufacturing plant was carried out as shown in Figure 1. The data taken for this study are based on data obtained from the battery factory of the Sebelas Maret University, and taken from some literature, the method used to process salt into a precursor is the solvay method and is the standard method in the calculation of this study.

The sodium cathode made in this study was a type of $NaNi_{0,5}Ti_{0,5}O_2$ using a mixture of $Ni_{0,5}Ti_{0,5}C_2O_4$ and Na_2CO_3. Then to make Na2CO3, salt raw materials from Pati district, Central Java were used. In the process of making $Ni_{0,5}Ti_{0,5}C_2O_4$, several main processes are used, including dissolved air with titanium, then manipulation of oxalic acid and nickel II sulfate is then carried out by filtering and drying.

Meanwhile, for the manufacture of Na_2CO_3, salt is purified and deposited with ammonium bicarbonate and then filtered and dried and in the furnace. After the furnace process, it is washed again using water and then dried again using the oven. After Na_2CO_3, this material is combined with the previously obtained material, namely $Ni_{0,5}Ti_{0,5}C_2O_4$. The two ingredients are mixed using a ball mill and refurnished to produce the desired material, namely $NaNi_{0,5}Ti_{0,5}O_2$.

Literatur Study **:** This research uses literature studies related to cathode and sodium, in addition, research on this study is the process to make cathodes from salt raw materials.

Data Collection **:** The data taken has several sources, The data taken relates to all the components needed in this research, related to process data, materials, and tools

Primary Data **:** Primary data in this study were taken through interviews with researchers through resource persons who are competent in research related to the manufacture of cathodes and the processes that occur in them so that the tools needed in the manufacturing process can be known.

Secondary Data **:** Secondary data obtained from this study came from various references related to material composition data, data on the process of making cathode active ingredients, data on tools used in making this cathode active ingredient.

Investment Feasibility **:** the data of the tools used in this study will be the basis for calculating the feasibility of investing in this study, although it is still on a lab scale.

Model Notation

p : Raw material
q : Labor
m : Process

Decision Variables :

$\sum_{p=1}^{P} BB$: Total Cost of Main Raw Materials
$\sum_{q=1}^{Q} BTK$: Total Cost of Labor
$\sum_{r}^{R} BT$: Total Cost of Additional Raw Materials
$\sum_{m}^{M} BP$: Total Cost of the Process
$\sum_{n}^{N} BO$: Total Operating Costs
∑ Dep : Total of Depreciation
∑ Ci : Total of Capital Interest
∑ Main : Total of Maintenance
∑ Sal : Total of Salary
∑CAM : Total Material Additive Costs
∑ CRM : Total Raw Material Costs
∑ E : Total Electrical Energy Costs
∑ P : Total testing fee
NPV : Net Present Value
CFt : Cashflow
FBP : Present Interest Factor
IRR : Internal Rate of Return
BEP : Break Event Point
S : Selling price / unit

Profit = Total Revenue – Total Cost
Total Cost of Production $= \sum_{p=1}^{P} BB + \sum_{q=1}^{Q} BTK + \sum_{r}^{R} BT + \sum_{m}^{M} BP + \sum_{n}^{N} BO$
Total Cost of Main Raw Materials $= \sum BB + BT_1 + BT_2 + ... + BT_n$
Total Cost of Labor $= TK_1 + TK_2 + ... + TK_n$
Total Cost of Process $= BP_1 + BP_2 + ... + BP_n$
Total Operating Cost $= BO_1 + BO_2 + ... + BO_n$
Total Fix Cost = ∑ Dep + ∑ Ci + ∑ Main + ∑ Sal
Total Var Cost = ∑CAM + ∑ CRM + ∑ E + ∑ P

$$\mathbf{NPV} = \sum_{t=0}^{n} CFt(FBP)t$$
$$\mathbf{IRR} = iNPV_{+} + \frac{NPV_{+}}{|NPV_{+} + NPV_{-}|} + (iNPV_{-} + iNPV_{+})$$
$$\mathbf{BEP} = \frac{FC}{S - VC}$$

4. Results and Discussion

4.1Cashflow

The research carried out in this study has cash flow of income and expenses needed to develop cathode active ingredients from sodium. The total investment value includes the investment costs for equipment and factory installations, the amount of which is 15% of the total investment cost for production equipment. And for the monthly production capacity is 60kg/month. Cashflow at this factory can be seen in Table 2.

Table 2 Cashflow

Period t	Cashflow	
	Cash Out (Rp)	Cash In (Rp)
0	556.160.896	0
1	955.271.364	1.080.000.000
2	991.542.727	1.080.000.000
3	955.271.364	1.080.000.000
4	991.542.727	1.080.000.000
5	955.271.364	1.080.000.000
6	991.542.727	1.080.000.000
7	955.271.364	1.080.000.000
8	991.542.727	1.080.000.000
9	955.271.364	1.080.000.000
10	991.542.727	1.128.361.817

4.2Investment and Procurement

To produce sodium cathode active ingredients, investment and procurement of raw materials for production are required, so this is a consideration in determining the price of the tool in order to get the best price to minimize investment costs. Some of the selected tools and their price list in table 3.

Table 3. Investment

Type of investment	Price (Rp)	Economic age (Year)
Filter press plate and frame	29.510.170	10
Atmospheric muffle furnace	43.530.000	10
High pressure hydrothermal reactor	281.720.000	10
Ball mill	45.500.000	10
Oven	12.800.000	10
Belt conveyor	14.000.000	10
Collection tank	15.000.000	10
Water tank	4.600.000	10
Water pump	600.000	10
Slury pump	10.358.000	10
Pheristaltic pump	26.000.000	10
Installation	72.542.726	10
Total	556.160.896	10

In this paper, the data used is the total cost used on the process of making cathode active material using salt as raw material. The scale used is a scale for laboratory production. The installed capacity for 1 production process is 10 kg and the composition of the costs used is shown in table 4 and table 5.

Table 4. Cost Parameter

Parameter	Number	Units
Cost of Production	132,677	Rp/100 gram
Selling Cost	150,000	Rp/100gram

Table 5. Table of Production Costs and Income

Item	Total	Item

production per year	720	kg/year
variable cost	94,033.02333	Rp/ 100 gram
	67,703,777	Rp/Year
fix cost	IDR 38,643.55	Rp/100 gram
	27,823,360	Rp/Year
total cost	132,677	Rp/ 100 gram
	95,527,136	Rp/Year
Price	150,000	Rp/100 gram
Income	108,000,000	Rp/Year
Profit	12,472,864	Rp/Year
BEP	497.14	Kg
Total Investment	556,160,896	Rp
NPV	79,162,916	Rp
IRR	17,42%	

Table 1 shows the data that the cost of goods manufactured per 100 grams of product is Rp. 132,677 and the product price per 100 grams is Rp. 150,000. So that there is a price difference between the Cost of Production and the selling price, the product profit per 100 grams of product is Rp. 17,323. From these data, it shows that the production of active cathode materials on a laboratory scale is still feasible. Comparingto the price of cathode active ingredients made of lithium, the price per 100 grams reaches Rp. 250,000, the cathode active material made from sodium has a higher economic value thus the price is very competitive with lithium. It can even be said that cathode active ingredients made from sodium are much cheaper than lithium.

To restore the total cost to reach the Break Event Point (BEP) is when a total of 497.14 kg of active cathode material has been produced. Annual income or profit for 1 year with the installed capacity of the laboratory which is 10 kg in a single process is Rp. 12,472,864 / Year, the NPV value under normal conditions is 63,591,706, and the IRR value is 17.42%. So it can be concluded that the investment in making this cathode active material is feasible.

4.3Sensitivity Analysis

The sensitivity analysis has 2 scenarios, the first is if the investment cost increases by 30% and if it gets subsidized costs from the government so that it can reduce the costs that must be incurred to develop the active ingredient sodium cathode. When the investment cost increases to 30%, the NPV obtained is Rp.-81,493,745 and the IRR is 4.18%, it can be concluded that if the investment cost has increased by 30%, this investment can be said to be unfeasible. Meanwhile, for the second scenario, if the development of the cathode active material receives 30% assistance from the total investment cost, the NPV obtained is Rp. 208,677,157 and has an IRR value of 24.89% so that the investment becomes more feasible because it gets subsidies from the government so that it can reduce the costs incurred for investment.

5. Conclusion

The conclusions of this paper is the costs obtained in the production process of active cathode materials are as follows: Cost of production per 100 grams is Rp. 132,677; the market price of the active cathode is Rp. 150,000 thus the price of the sodium cathode active ingredient can have a profitable economic value. That is why it is very worthy of further study concerning its economic value. In addition, cathode active material made from lithium is much more expensive when compared to cathode active material made from sodium. The price of lithium raw material has a price of Rp. 250,000 per 100 grams and sodium cathode active ingredient Rp. 150,000. This potential can potentially be chosen by factories that produce batteries because it will cut production costs at battery factories. Further studies that can be carried out in this research is the expansion of production to an industrial scale. because in laboratory production conditions it can be said that it is feasible for production or scale up.

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