Cost-Benefit Analysis of Palm Kernel Shells as a Diesel Fuel Substitution for Hot-Mixed Asphalt

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Abstract. Indonesia is one of the biggest oil palm producing countries. Solid waste from processing palm oil into crude palm oil (CPO) includes palm shells. This palm shell waste can be used as an alternative to diesel fuel for aggregate heating. This study aims to analyze the investment of the use of palm shells as an asphalt burner replacing diesel. Primary data were obtained from field and laboratory identification. In contrast, secondary data were obtained from relevant agencies, the Department of Public Development and Public Housing, PT Bara Energi Biomass and PT Damai Citra Mandiri. The method used is a quantitative descriptive analysis by calculating the annual costs and benefits over the machine's life, ten years. This study uses the Cost-Benefit Analysis. Four investment criteria are calculated: (1) Net Present Value (NPV), (2) Benefit-Cost Ratio (BCR), (3) Payback period (PbP), (4) Internal rate of return (IRR). The results found that palm shells use as an asphalt burner for diesel substitutes showed high costs and top benefits. The calculation of economic feasibility with investment criteria shows that the NPV has a positive value, which means it is feasible. BCR shows a ratio of costs and benefits is more than one; it indicates that investment in asphalt production activities is feasible. The calculation of investment in replacing diesel fuel with palm shells shows a positive value of PbP since the first year. The internal rate of return shows that the investment value has met the minimum standard of general interest or replacement.

Keywords: palm shell, hot-mixed asphalt, aggregate heating, bioenergy, cost-benefit analysis

1. Introduction

There are two problems in utilizing natural resources: scarcity and dilemma in its utilization [4, 11]. The continuous use of non-renewable resources, such as fuel oil, can cause scarcity. Indonesia is a country that has excellent natural resource potential. Long-term energy management has become the government's concern, and various policies have been issued to optimize sustainable energy management [10]. One of these natural resources is infrastructure development, such as connecting roads between regions and provinces. So far, asphalt burners use non-renewable diesel fuel, so an alternative raw material for asphalt burners is needed. One alternative to substitute diesel fuel for asphalt
burning machines is palm kernel shells. Indonesia is one of the largest palm oil-producing countries. Solid waste from processing palm oil into crude palm oil (CPO) includes palm kernel shells. Indonesia has 1,688 companies engaged in the palm oil plantation industry. The largest palm oil plantations are found in 5 provinces, including Riau, West Kalimantan, North Sumatra, South Sumatra, and Central Kalimantan. The land area of Indonesia's oil palm plantations is 15.7 Million Hectares and is still growing. Based on the data, there is a potential palm shell of 10.4 million tons metric that can be utilized. During this time, palm kernel shells are used for energy and material mixtures [12]. As energy, palm kernel shells are used for dyer or broiler fuels. As a mixture of materials, palm shells are used as biomass because they contain ash important to the soil. The palm shell price is also still relatively low, which is around IDR 800,00 per kg [5].

The abundance of palm kernel shells is then processed into fuel for burning asphalt [2,6]. Before undertaking an asphalt burner construction project, a cost-benefit analysis is necessary. The aim is to determine the number of costs required during the project and know the future benefits. Pranolo et al. [7] studied the use of palm shells for gas reduction emissions using a life-cycle analysis to reduce gas emissions instead of diesel fuel. Cost-benefit analysis has been done to calculate renewable energy, as in research [3], which measures electricity production's economic viability from small-scale renewable energy sources. Research on the cost-benefit analysis of using palm kernel shell as a replacement diesel fuel for asphalt burner has not been done much.

2. Methodology

Diesel is a fuel that cannot be renewed. Meanwhile, palm shells are fuel from nature and will be returned to nature to form sustainable natural management. The research uses a descriptive quantitative analysis method. The data used are primary data and secondary data. Primary data were obtained from field and laboratory observations, while secondary data were obtained from the Public Development and Public Housing Agency, PT Bara Energi, and related agencies. The analysis tool used is the cost-benefit analysis.

Cost-Benefit Analysis (CBA) calculates the overall costs and benefits used during economic life [9]. The economic age used in production activities using palm shells as an asphalt burner to replace diesel is 10 (ten) years. During the project's life, it is necessary to calculate the addition or reduction of the costs used.

The cost-benefit analysis uses four investment criteria. These investment criteria include Net Present Value (NPV), Benefit-cost ratio, Payback Period, and Internal rate of return.

2.1. Net Present Value (NPV)

Conducted to determine the difference between the present value of benefits and the flow of costs. The NPV calculation is

\[ NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1 + i)^t} \]

Where

- \( B_t \): the benefits obtained per year
- \( C_t \): costs incurred each year
- \( n \): number of years
- \( i \): interest rate (discount)

Based on the NPV result, the investment eligibility criteria are if the NPV > 0 means that the project is declared profitable and feasible to be implemented. Suppose the NPV < 0; then the project does not produce the cost value used or is not feasible to implement. Moreover, if NPV = 0, then the project can return the initial capital, or the project will experience a balanced level of profit [1].
2.2. Benefit-Cost Ratio
To calculate this ratio, it is necessary first to calculate the net benefit each year. From this, we can see that there are years with positive net benefits (where the gross benefits are more significant than the costs), and there are years that have negative net benefits, where the gross benefits are smaller than the costs [1].

\[ BCR = \frac{\sum DB}{\sum DC} \]  

(2)

where

\( DB \) : Discounted benefit

\( Ct \) : Discounted cost

If the B/C ratio is > 1, then the project is feasible to run; the B/C ratio < 1, the project suffers a loss and is not feasible to run, and the B/C ratio is - 1, then the project is neither profitable nor loss [1].

2.3. Payback Period
The Payback Period is used to determine the payback period for an investment made.

\[ Payback \ period = \frac{I}{Ab} \]  

(3)

Where

\( I \) : the amount of investment required

\( Ab \) : the net benefit of the discount that can be obtained each year

A reasonable payback period is less than the defined project life.

2.4. Internal Rate Of Return (IRR)
The purpose of calculating the IRR is to determine whether an investment is profitable or whether it has met the minimum standard of interest or general return. Therefore it is often called the minimum attractive rate of return. The IRR method is also commonly called the "Economic Rate of Return" in economic analysis or the "Financial Rate of Return" in financial analysis. The IRR basis is which makes the Present Value of the net results as long as the project runs the same as zero. The method used is the trial and error method (trial and error system), namely by determining two or more interest rates, where the actual rate of interest is between the interest rates. By calculating the present worth (cash price), IRR can be calculated through interpolation [1].

\[ IRR = i + \frac{NPV}{NPV - NPV'} (i' - i) \]  

(4)

Where

\( i \) : Discount rate that results in a positive NPV

\( i' \) : Discount rate that results in a negative NPV

\( NPV \) : NPV is positive

\( NPV' \) : NPV is negative

3. Result and Discussion

3.1. Asphalt Mixing Plant Cost using Diesel Fuel

3.1.1. Investment costs. Investment costs are some costs incurred for business activities in goods with a certain benefit age. Investment costs used in asphalt burner and economy calculation activities with diesel fuel include 1 unit of a solar burner and ready-to-install solar tank worth IDR 220,000,000,-Tax for equipment purchased 10 percent worth IDR 22,000,000,-. The cost of making machine placement
in the form of building a house of 10 M2 amounting to IDR10,000,000,-. The total investment cost of burning asphalt with diesel fuel is IDR 252,000,000,

3.1.2. Production cost. Production costs are the costs incurred to produce a product in the business. These costs include the cost of raw materials and fuel. The fuel used is a diesel with 16 litres/minute with a price per litter of IDR 9,000,-. The operating time is 8 hours a day, so the cost of Solar is IDR 69,120,000,-. The total cost of production is IDR 69,120,000.00

3.1.3. Operational cost. Operational costs are associated with workmanship during businesses such as electricity and labour. Electricity needed for 25 Kwh with a price of IDR 1,467,- for 8 hours. The number of electricity costs IDR 293,400,- per day. Diesel fuel as an asphalt burner does not use human labour; it only uses tools. Total operating expenses are IDR 293,400,-

3.1.4. Other costs. Miserly or contingency costs must be added to the project costs, due to changes or errors in calculations. The total contingency cost stipulated is 5 percent of the total amount of IDR 16,070,670,

| No | Cost                  | IDR    | USD (1 USD = IDR 15,000) |
|----|-----------------------|--------|--------------------------|
| 1  | Investment Costs      | 252,000,000 | 16,800                   |
| 2  | Production Costs      | 69,120,000  | 4,608                    |
| 3  | Operational Costs     | 293,400  | 20                       |
| 4  | Other Expenses        | 16,070,670 | 1,071                    |
|    | Total                 | 337,463,400 | 22,499                   |

Source: Primary data, 2020

Based on the calculation of these costs, to produce 384 Tons of HMA, it takes a fee of IDR 337,463,400.00. The production cost of 1-ton HMA using diesel fuel is IDR 878,810.9375 or USD 59.

3.2. Asphalt Mixing plant cost using Palm Kernels Shells

The costs required for burning asphalt using palm kernel shells once consist of investment costs, production costs, operational costs, and taxes.

3.2.1. Investment costs. These costs include purchasing a gasifier BE-170 dryer heater for IDR 742,000,000, a 10 percent gasifier tax of IDR 74,200,000, and a single unit BE-76 asphalt boiler heater for IDR 247,000,000, along with a 10 percent tax of IDR 24,700,000. However, since the machine is assumed to be ten years old, the machine price and taxes are divided by ten so that the total cost of the device is IDR 108,790,000 per year. The casting of reinforced foundations, placing gasification machines and boiler heaters with a length of 16 meters, a width of 15 meters, a thickness of 15 m³ and 5 m³ of IDR 30,500,000, construction of a machine protective roof of IDR 25,000,000, a cooling water circulation tub of IDR 16,000,000, construction of a warehouse for storage of shells with an area of approximately 200 m², amounting to IDR 40,000,000, and delivery of machines from Surabaya to the Asphalt Mixing Plant location of IDR 30,000,000. The total investment cost of an asphalt burner using palm kernel shell fuel is IDR 1,229,400,000.

3.2.2. Production costs. Production costs include the cost of raw materials, namely palm kernel shells. The heating machine requires 50 kg/minute of palm shells in one production, which costs IDR 800 per kg. The determination of oil palm shells' price is influenced by the distance to the palm oil mill. The total production cost is IDR 19,200,000.
3.2.3. **Operational costs.** These costs consist of electricity, labour, water circulation, diesel fuel for the multitasking loader, maintenance of the shell storage, routine maintenance, and gearbox oil changes. Electricity for an asphalt burning machine with palm shell raw materials requires 45 KwH for one production day or 8 hours at the cost of IDR 528,120. Labour needs three people, with a production day cost of IDR 175,000. The workforce includes gasifier operators, boiler operators, and AMP operators. The total cost of labour is IDR 525,000. The water circulation in question is a cooling pool that requires the addition of 1 m3 of water. The water circulation fee is IDR 10,000 per hour. Engine maintenance costs include oil gearbox and minor damages estimated at IDR 48,000,000. The cost of shrinks and buildings is calculated using linear methods to vary from year to year. The total amount of operational and maintenance costs is IDR 1,484,648,800 per year.

3.2.4. **Other expenses.** Costs that must be added to project costs due to changes or errors in the calculation are 5 percent of the total investment costs, operating costs, and production costs IDR 16,257,156. The total contingency cost for oil palm shell fuel is IDR 463,863,078 in the first year.

Table 2 shows that the total investment costs, production costs, operational and maintenance costs, and taxes, an output of 384 tons per day of HMA, is IDR 287,400,276.00. Cost production for 1-ton HMA using palm kernel shells is IDR 748,438.21 or USD 50. The cost-benefit analysis calculation uses a cost per year data so that the figure is calculated to be per year, as shown in table 2.

**Table 2.** Cost summary of palm kernel shells use as fuel per day and per year.

| No | Cost                  | Cost per day (IDR) | USD (1 USD = IDR 15,000) | Cost Per Year |
|----|-----------------------|--------------------|--------------------------|--------------|
| 1  | Investment Costs      | 250,290,000        | 16,86                    | 1,229,400,000|
| 2  | Production Costs      | 19,200,000         | 1,280                    | 7,252,612,755|
| 3  | Operational Costs     | 1,653,120          | 110                      | 1,484,648,800|
| 4  | Other Expenses        | 16,257,156         | 1,084                    | 463,863,978  |
|    | **Total**             | **287,400,276.00** | **19,160**               | **10,430,524,633** |

Source: Primary data, 2020

3.3. **Benefits**

The analysis of the benefits of using palm kernel shells as an alternative to asphalt burners is divided into direct and indirect benefits. Direct benefits are benefits whose amounts are immediately known due to production activities. Meanwhile, indirect benefits are other benefits received outside of production activities.

3.3.1. **Direct benefit analysis.** Direct benefits due to palm kernel shells as raw material for asphalt burners are obtained from selling Hot Mix Asphalt (HMA) and cost savings due to changes in raw material costs from palm kernel shells.

- **Hot Mix Asphalt Sales.**
  
The output produced by the gasifier engine during one shift or for eight operating hours is 384 tons of HMA. The selling price of 1 ton of HMA varies depending on the type, including Hot mix AC BC, Hot mix AC WC, Hot mix III Laston, Hot mix III Laston special, hot mix HRS, and Hot mix Sand Sheet. The average price for this type of hot mix is IDR 1,151,667. If the output produced is 384 tons, then the benefits received in one production shift for 8 hours are IDR 442,240,000 per day.

- **Fuel Savings.**
  
Apart from the sale of hot mix, the direct benefit received from the change in fuel from diesel to palm kernel shells is fuel savings. The price of diesel is lower than the price of palm kernel shells. The savings made are the amount of diesel needed minus the price of the required palm shells. Total observations made are IDR 45,600,000 per day.
3.3.2. **Indirect benefit analysis.** The indirect benefits that are felt are reduced emissions and savings in foreign exchange.

- **Emission Reduction.**
  The indirect benefit that can be felt from using palm kernel shells for engine fuel is the resulting reduction in emissions [8]. The assumption used is that the asphalt burning machine operates for eight (8) hours in one day. When using diesel fuel, the resulting emission is 13.3632 tons CO2Eq per day, but using combustion biomass gasification using palm kernel shells, the resulting emissions are 7,968 tons of CO2Eq per day. The consequent reduction in emissions is the difference from this value. Combustion using palm kernel shell fuel has succeeded in reducing emissions by 5.3952 tons of CO2Eq per day. The assumed price of 1 ton CO2 Eq is the US $ 5, and the rupiah assumption is IDR 14,000. The emission reduction that has been done is IDR 70,000 per ton. Then the total emission reduction benefit is IDR 377,664 per day or IDR 90,639,360 per year.

- **Foreign Exchange.**
  The use of palm shells as a substitute for diesel fuel can save the country's foreign exchange because 80 % of the gasification equipment material is obtained from local materials. As much as 20 % is still imported. The equipment purchased was a Gasifier BE-170 Heating Dryer for IDR 742,000,000.00 and a BE-76 Asphalt Kettle Heater for IDR 247,000,000. The total purchase plus 10% VAT is IDR 1,087,900,000.00. Calculation by Domestic Component Level. Then there was a saving of IDR 870,320,000 in foreign exchange.

**Table 3. Total Benefits per year.**

| No | BENEFITS                  | PRODUCTION/ DAY | UNIT | IDR/TON | BENEFITS IDR/DAY | TOTAL BENEFITS IDR/YEAR |
|----|--------------------------|-----------------|------|---------|-----------------|------------------------|
| A  | Direct Benefits          |                 |      |         |                 |                        |
| 1  | Hot mix Sales            | 384 ton         | 1,151,667 | 442,240,000 | 106,137,600,000 |
| 2  | Fuel Savings             |                 |       |         | 49,920,000      | 11,980,800,000         |
|    | Subtotal A               |                 |       |         | 118,118,400,000 |                       |
| B  | Indirect Benefits        |                 |      |         |                 |                        |
| 3  | Emission Reduction       | 5.3952 ton CO2eq | 70,000 | 377,664 | 90,639,360     |                        |
| 4  | Foreign Exchange         |                 |       |         | 870,320,000    | 960,959,360            |
|    | Subtotal B               |                 |       |         |                 |                        |
|    | **TOTAL BENEFIT A+B**    |                 |       |         | **119,079,359,360** |                       |

Source: Primary data, 2020

Based on Table 3, the total benefits both directly and indirectly in hot mix production using palm kernel shell fuel for one year amounted to IDR 119,079,359,360.

3.4. **Cost-Benefit Analysis**

After obtaining the total costs and benefits for each year, the benefit costs are calculated. Table 3 shows the total costs and benefits.
Table 4. Costs and Benefits per year of palm kernel shells use as a substitute for diesel fuel.

| Year | Cost       | Benefit    |
|------|------------|------------|
| 1    | 10,430,524,633 | 119,079,359,360 |
| 2    | 9,059,895,133   | 107,595,279,360 |
| 3    | 8,961,415,633   | 96,981,519,360  |
| 4    | 8,831,436,133   | 86,367,759,360  |
| 5    | 8,732,956,633   | 75,753,999,360  |
| 6    | 8,602,977,133   | 65,140,239,360  |
| 7    | 8,504,497,633   | 54,526,479,360  |
| 8    | 8,374,518,133   | 43,912,719,360  |
| 9    | 8,260,288,633   | 33,298,959,360  |
| 10   | 8,146,059,133   | 22,685,199,360  |

Source: Primary data, 2020

In Table 4, in the cost column, it can be seen that there is a fluctuation in the total value per year because there are additional and subtraction costs for operational costs. The operating costs are in the form of machine maintenance every three years.

3.4.1. Net Present Value. An essential step in determining the NPV is that both the benefits and costs each year must be calculated in cash price, then compared. Each cost and benefit must be found in real value in the initial year (year 0) or discounted. A project is said to be a "go project" if the NPV value = 0, especially in economic analysis. Meanwhile, for financial analysis, NPV should be > 0.

\[
NPV = \sum (\text{Net benefit} \times \text{Discount Factor})
\]

NPV = 429,243,328,916.56

The calculation result shows that the net present value is positive or NPV > 0. It indicates that the replacement of fuel from diesel fuel to palm kernel shells is feasible. NPV results are positive during the project period (10 years); the initial capital/investment invested can generate IDR429,243,328,916.56 making it very profitable.

3.4.2. Benefit-Cost Ratio. The next investment criterion is the Benefit-Cost Ratio (BCR), which aims to determine the cost and benefit ratio. Business activity is feasible if the gross B/C ratio of the project is ≥ 1.

\[
BCR = \frac{\sum DB}{\sum DC}
\]

BCR = \frac{484,171,363,572}{54,928,034,655}

BCR = 8.81 > 1

A BCR of more than 1 means that the project to replace diesel fuel with palm kernel shells is feasible to run. B-C ratio compares the current amount of value on benefit flows, and cost flows based on the cost of capital (OCC) opportunities. The OCC is the level of return if capital is invested in the best and easiest possible. B-C ratio is > 1, so the investment in the use of palm shells as a solar substitute for asphalt burners is feasible. The payback period is a calculation used to determine which year the NPV can show a positive value. The calculation of changing diesel fuel to palm kernel shells for asphalt burners has had a positive NPV since the first year.
3.4.3. Payback period. PbP analysis is used to determine the length of time it takes for the initial capital return and project time. Results show PBP 1 year or less of the project's life, which means that the project has been profitable since the first year the investment was run.

3.4.4. Internal rate of return. The internal rate of return is an indicator of the level of profit stated in the percentage. In this calculation, the IRR is more than 100% because NPV has a significant value.

4. Conclusion
Based on the calculations that have been done, the conclusions that can be obtained are as follows
a. The cost comparison of diesel fuel and palm shell is quite significant. Production costs for 1-ton HMA are USD 59 for diesel fuel and USD 50 for palm shell fuel. Thus, the difference is USD 9 or equivalent to IDR 120,000 – IDR 150,000.
b. The cost used to produce Hot Mix Asphalt in one year produces an output of 384 tons per day using oil palm shell as fuel is IDR 10,430,524,633. These costs consist of investment costs, production costs, operational and maintenance costs, and taxes. The benefits to be obtained either directly or indirectly in the hot mix production per year are IDR 118,042,559,360. The immediate benefits consist of selling hot mix and saving on raw materials. Meanwhile, indirect benefits consist of reduced emissions and savings in foreign exchange.
c. The benefit-cost analysis shows that NPV> 0, Benefit-Cost Ratio> 1, the payback period is less than the project life, and the IRR is less than the prevailing interest rate. It shows that the project using palm kernel shells as an asphalt burner to replace diesel fuel can be implemented in terms of benefits and costs.

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References
[1] Rahardjo M 2010 Studi Kelayakan Proyek Cakra books, Surakarta
[2] Asadullah M, Adi A M, Suhada N, Malek N H, Saringat M I, and Azdarpour A 2014 Optimization of palm kernel shell torrefaction to produce energy densified bio-coal Energy Conversion and Management 88 1086–1093
[3] Atănăsoae P, Pentiuic R D, Milici D L, Olariu E D, and Poienar M 2019 The Cost-Benefit Analysis of the Electricity Production from Small Scale Renewable Energy Sources in the Conditions of Romania Procedia Manufacturing 32 385–389
[4] Barbier E B 2013 Economics, Natural-Resource Scarcity, and Development (Routledge Revivals): Conventional and Alternative Views Routledge
[5] Olutoge F A 2010 Investigations on Sawdust and Palm Kernel Shells As Aggregate Replacement ARPN Journal of Engineering and Applied Sciences 5 (4) 7–13
[6] Osei Bonsu B, Takase M, and Mantey J 2020 Preparation of charcoal briquette from palm kernel shells: a case study in Ghana Heliyon 6 (10) e05266
[7] Pranolo S H, Setyono P, and Fauzi M A 2020 Life cycle analysis of palm kernel shell gasification for supplying heat to an asphalt mixing plant Waste Disposal & Sustainable Energy 2 (1) 55–63
[8] Rashidi N A, and Yusup S 2017 Potential of palm kernel shells as activated carbon precursors through a single-stage activation technique for carbon dioxide adsorption Journal of Cleaner Production 168 474–486
[9] Santoso L W, and Wirawan A 2015 Analisis Investasi Sistem Informasi Akademik pada Universitas X dengan Metode Cost Benefit Analysis (CBA) Petra Christian University

[10] Sugiyono A 2014 Permasalahan dan kebijakan energi saat ini Prosiding Peluncuran Buku Outlook Energi Indonesia 2014 & Seminar Bersama BPPT Dan BKK-PI. Jakarta: Badan Pengkajian Dan Penerapan Teknologi 9–16

[11] Suparmoko M, Hendarto E, Setyarko Y, and Widyantara G 2003 Valuasi Ekonomi Sumberdaya Alam Kabupaten Sikka

[12] Thiagarajan J, Srividhya P K, and Balasubramanian P 2018 Thermal behaviour and pyrolytic kinetics of palm kernel shells and Indian lignite coal at various blending ratios Bioresource Technology Reports 4 (July) 88–95