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# Economic Age of Boilers of Oil Palms *(Elais)* Factory of North Sumatra, Indonesia

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**Abstract**

Maintenance management of machinery in factory depends on the calculation of their economic usage. The purpose of this study was to determine the economic life of boilers in the Government Plantation Enterprises (PTPN II) North Sumatra Province. As a consideration for the replacement of boiler engines in the Government Plantation Enterprises (PTPN II) Tanjung Garbus Pagar Merbau, the research for determining the economic age was carried out. The engineering and forecasting economics average annual cost and cost forecasting for the next few years were conducted. In the Government Plantation Enterprises (PTPN II) for *Elais* (oil palms) Tanjung Garbus Pagar Merbau had been found a problem such. There is no determination to calculate the economic life of machine. This calculation is focused on the boiler engine. The data show that the average annual cost, the most economical life of the boiler is around 10 years, i.e in 2005, where the minimum annual cost of boiler is the minimum of IDR. 984.805.587. This average annual cost is obtained after forecasting costs, i.e operating costs and down time costs calculation of capital recovery. With the knowledge of the boiler's economic life, it is better for the company to consider replacing the boiler.

***Key words:*** Economic age; boilers; forecasting; cost.

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## 1. Introduction

The machinery and equipment that is used have the ability to produce, but economically a machine and equipment is not always profitable to be used during its operation. The increasing age of machines and equipment, the costs incurred increase. This is because the declining condition of machinery and equipment needs to be investigated, so the total cost of production can be suppressed. The company may have limited space or because of the company's own circumstances so that the company does not calculate the economic life of its equipment but it does not mean that the company does not find any way to achieve its economic life.

The machine chosen in this study is Boiler engine owned by the Government Plantation Enterprises (PTPN II) OIL Palms in Tanjung Garbus Pagar Merbau of North Sumatra. The choice of boiler machine as a research because the age of boiler machine belonging to that company which is old, where boiler machine used from 1995 until now; so that boiler machine worth to be examined. The Boiler Engine serves as an energy conversion plane that converts chemical energy (potential) from fuel to thermal energy. Operating a Boiler requires a cost, which costs tend to rise and decrease according Boiler usage. In this case the cost that tends to rise each year is the cost of maintenance and fuel, while the cost decreases every year is a payback fund. Each maintenance and fuel cost is searched for its equivalent function using forecasting method and then summed to obtain the average annual average cost equation function as a function of the economic life of the least annual total cost.

The purpose of this determination of the economic life of this Boiler is to create a profitable Boiler replacement schedule for the company from the analysis by using the method of minimizing the average annual cost mathematical model to obtain the conclusions of Boiler's economic life so that the company can consider the replacement of the Boiler.

With regard to the background of existing problems, then the main problem is to determine how much the average annual cost of Boiler engine so it is known the economic age of the Boiler engine in the Government Plantation Enterprises (PTPN II) in Tanjung Garbus Pagar Merbau of North Sumatra.

## 2. Review of Literature

### *2.1. Boiler*

In the process of oil palm processing, it occurs several stages of the process that requires energy needs. The greater the production capacity, the higher the additional energy required in the production process. Likewise, this energy demand is increasing in line with the increase of palm oil production. The Palm Oil Factory fulfills its energy needs independently using solid waste in the form of fiber and shells for Boiler fuel. Boiler is steam-producing installations used to drive Steam turbines as power in palm oil mills. Can be said Steam turbine is used to generate electrical power. In addition, the steam from the Boiler is used for boiling (sterilizer) and heating in the processing unit.

According to Muin [1], boiler is a heat engine (thermal engineering) that transfers chemical energy or automated energy into work (effort). Boiler is a tool to produce steam, which consists of two important parts: the kitchen heating, generating heat obtained from fuel combustion and boiler proper, a tool that converts water into steam

[2]. The boiler is a closed vessel in which the combustion heat is flowed into the water until a hot water (steam) of about 2500-3000$^o$F is formed [3]. The boiler is a closed vessel where the combustion heat is flowed into water until hot or steam water is formed [4]. Hot water or steam at a certain pressure is then used to drain heat to a process. Water is a useful and inexpensive medium for delivering heat to a process. If the water is boiled down to steam, the volume will increase by about 1,600 times, producing a power that resembles an explosive gunpowder, so the boiler is a device that must be managed and maintained very well. Boiler basically consists of a drum that is closed at the end and base, where on the inside of the drum there are pipes that serve to drain water or hot gas.

Based on the fluid flowing in the pipe, the boiler is classified into:

a. Fire tube boiler, this type of boiler on the tube flows with combustion gases and other parts that sell water flowed to be evaporated. The tubes are instantly cooled by the water that protects them. The pass number of the boiler depends on the amount of the horizontal passage of the combustion gas between the furnace and the fire pipe. The combustion gas on the furnace is calculated as the first pass. This type of boilers is widely used for processing industries ranging from small to medium scale [5].

b. Water tube boiler is widely used for large-scale steam needs. The working principle of the water pipe boiler is contrary to the fire pipe, the combustion gas from the furnace is passed to the pipes containing the water to be evaporated [5].

### *2.2. Palm oil*

Palm oil is one of the most important plantation crops in the agricultural sector, and the plantation sector in particular. This is because of the many plants that produce oil or fat, oil palm that produces the largest economic value per hectare in the world [6].

Oil palm cultivated consists of two types: E. guineensis and E. oleifera. The first type of the widest cultivated person from both these species of oil palm has their respective advantages. E. guineensis has a very high production and E. oleifera has a low plant height. Many people are crossing these two species to get a species that is high in production and easy to harvest. E. oleifera is now beginning to be cultivated as well to add to the diversity of genetic resources.

According to Setyohadi palm oil superiority as a food is as an anti-cancer and tekoferun as a source of vitamin E, which includes anti-oxidant substances. Another advantage of linoleic acid content is low so that cooking oil made from coconut fruit has stability [7].

The type of oil palm based on the thickness of its shell, which consists of: Dura, Pisifera, Tenera. Dura is a palm whose fruit has a thick shell that is considered to shorten the life of processing machines but usually large fruit bunches and oil content per cluster ranges from 18%. Pisifera fruit does not have a shell, so it does not have a core (kernel) that produces economical oil and sterile females so very rarely produce fruit. Tenera is a cross between the parents of Dura and the male Pisifera. This species is regarded as a superior seed because it complements the deficiencies of each parent with the nature of thin fruit shells but females remain fertile. Some superior Tenera have a percentage of meat per fruit reaching 90% and the oil content per bunch can reach 28%. Based on the color of the palm fruit is divided into 2 types, among others: 1.

Characteristics Type Higrescens - Characteristics: Raw raw fruit (purple) to green at the end, while pale slightly pale after baked turns into reddish yellow. 2. Character Type Virescens: Raw fruit is green after cooked into reddish orange but the tip is still greenish. The process of oil formation in the fruit lasts for 24 days, ie when the fruit starts cooking. Harvesting done before the oil formation process is complete will produce less oil, while the harvest after the oil formation process is completed will be detrimental because many fruits are loose and fall to the ground.

Fruit that is too much of some oil content will turn into free fatty acid that produces low quality palm oil. Good coconut planting is: all mature bunches must be harvested, fruit bunches cut with dodos or tree trunks, bark marks should be curved like hooves tilted tilted, leaf leaves cut from the tree must be stacked regularly in *Gawangan* and at face down.

### *2.3. Palm Oil Industry*

The rapid development of oil palm plantations is inseparable from the very promising level of profitability of this business. The high level of profit is allegedly influenced by the price factor of Fresh Fruit Bunches (FFB) which is always increasing significantly. In the period 2002-2011 the price of FFB has jumped sharply to more than threefold. The income level of palm oil plantation growers is much larger than other agricultural commodities allegedly caused not a few other commodity farmers who switched to oil palm plantations.

The high price increase of FFB has prompted many people to invest in oil palm plantations. Some people started oil palm plantation business as a new business but some other people who have been working on other agricultural commodities such as rubber and rice are not the few who turned to oil palm crops. The palm oil industry is used by companies to gain profit.

Oil Palm Plantation in Indonesia is currently one of the very large export commodities in Indonesia [8]. The development of the palm oil industry is currently very rapid, with an increase in the number of oil palm production in line with the increasing needs of the community. The amount of production that can be produced has a positive impact for the Indonesian economy. In the future, the palm oil industry can be expected to become the motor of national economic growth.

## 3. Research Methods

### *3.1. Place and time of research*

This research was conducted at boiler station at the government plantation enterprise (PTPN II) for elais oil palms of Tanjung Garbus Pagar Merbau. It is used for CPO production located in Merbau of Deli Serdang District. The time of the research is done when doing field work practice.

### *3.2. Types and Data Sources*

Types of data obtained were two types:

1. Primary Data

Primary data were obtained from the observation, measurements and interviews conducted on workers. The required data are as follows:

a. Boiler Machine Specification Data.
b. Boiler Machine Price Data
c. Fuel Cost of Boiler Machine.
d. Boiler Machine Lubricant Cost Data.
e. Data Replacement Cost Spare Parts.
f. Data Hours Operation and Clock Boiler Repair machine.
g. Boiler Operators Wage Data

2. Secondary Data

Secondary data were obtained from library search and information or data from company. In this study the required secondary data were as follows:

a. Company historical data
b. Business scope
c. Organizational structure of the company
d. Production process

### *3.3. Technique of Collecting Data*

To facilitate the smooth writing of bachelor's duties, then in need of a data collection method so that taken can be perfect and timely and cannot interfere with the work of the company. Data obtained from this company is done in several ways:

1. Making a direct observation.
2. Recording data and information available in the company.
3. Conducting interviews with the parties who provide the necessary information.
4. Reading books that can help solve problems.

### *3.4. Data Processing Technique*

Data obtained from data collection then performed data processing. The steps used in data processing are as follows:

### *3.5. Down Time Cost Calculation*

Down Time represents a loss of machine opportunity to operate because the machine is damaged or is being repaired. The cost of down time is calculated based on the machine repair hour per year divided by the normal machine working hours per year multiplied by the operator's cost each year (BO).

## 4. Results and Discussion

***4.1 The economical age of the boiler machine is found in the 10th year found in 2005***

***4.2 The total annual cost of the minimum average boiler engine is Rp. 984.805.587***

***4.3 The total annual cost of the average maximum boiler engine is Rp. 1.059.031.810***

## 5. Discussion

### *5.1. Calculation of Depreciation of Boiler Machine Annual*

Before depreciation (Capital Recovery) is calculated, it is necessary to determine the Present Value (P) of Boiler Engine for each year calculated based on the Declining Balance Method.

This method is often also called Methensen Formula. The comparative annual depreciation value of the cost value at the beginning of the year is constant throughout its lifetime.

The applicable formula: L = P (1-k) t; the value of C= 2 / n = 2/25 = 0.08

Where :

L = end price of machine at year n

P = Machine starting price

C = Constant

t = Year t

n = Machine in age

After the starting price of the machine (P) and the final price (L) per year Boiler is obtained, annual depreciation (CR) is determined by the formula:

CR = (P-L) (A / P, i, n) + Li

The preferred interest rate is adjusted to the bank deposit rate: i = 6%.

The payback funds for the first year (1996) up to the 25th year (2020) are calculated the same way. The results can be seen in table 1 below.

**Tabel 1:** Calculation of Boiler Machine Annual Depreciation

| **Year** | **(I-S)(A/P,6%,n)**<br><br>**(Rp)** | **Li**<br><br>**(Rp)** | **Capital Recovery**<br><br>**(Rp)** |
|---|---|---|---|
| 1996 | 436.720.000 | 284.280.000 | 721.000.000 |
| 1997 | 431.433.216 | 261.537.600 | 692.970.816 |
| 1998 | 426.383.018 | 240.614.592 | 666.997.611 |
| 1999 | 421.522.307 | 221.365.425 | 642.887.732 |
| 2000 | 416.810.339 | 203.656.191 | 620.466.530 |
| 2001 | 412.347.072 | 187.363.695 | 599.710.768 |
| 2002 | 407.826.819 | 172.374.600 | 580.201.419 |
| 2003 | 403.614.571 | 158.584.632 | 562.199.203 |
| 2004 | 399.600.239 | 145.897.861 | 545.498.101 |
| 2005 | 395.863.036 | 134.226.032 | 530.089.069 |
| 2006 | 392.048.799 | 123.487.950 | 515.536.749 |
| 2007 | 388.502.609 | 113.608.914 | 502.111.524 |
| 2008 | 385.103.622 | 104.520.201 | 489.623.823 |
| 2009 | 381.695.604 | 96.158.585 | 477.854.190 |
| 2010 | 378.583.542 | 88.465.898 | 467.049.440 |
| 2011 | 375.558.767 | 81.388.626 | 456.947.393 |
| 2012 | 372.254.717 | 74.877.536 | 447.132.254 |
| 2013 | 369.773.507 | 68.887.333 | 438.660.840 |
| 2014 | 366.797.989 | 63.376.346 | 430.174.336 |
| 2015 | 364.341.599 | 58.306.239 | 422.647.838 |
| 2016 | 361.757.535 | 53.641.740 | 415.399.275 |
| 2017 | 359.181.946 | 49.350.400 | 408.532.346 |
| 2018 | 357.174.790 | 45.402.368 | 402.577.159 |
| 2019 | 354.97.0279 | 41.770.179 | 396.740.458 |
| 2020 | 352.644.770 | 38.428.565 | 391.073.335 |

### *5.2. Calculation of Operating Expenses for Boiler of Year*

Operating cost of Boiler machine is the sum of fuel cost, spare part cost, lubricant cost, and wage of Boiler machine operator can be seen in following table

**Table 2:** Calculation of Boiler Machine Operating Costs

| Year | Lubricant cost per year | Spare parts cost per year | Fuel costs per year | Operator wages per year | Operating cost per year |
|---|---|---|---|---|---|
| 1996 | 440.000 | 720.000 | 33.400.000 | 269.400.000 | 303.960.000 |
| 1997 | 500.000 | 1.170.000 | 38.700.000 | 327.600.000 | 367.970.000 |
| 1998 | 620.000 | 1.725.000 | 42.200.000 | 345.360.000 | 389.905.000 |
| 1999 | 700.000 | 2.220.000 | 54.000.000 | 345.600.000 | 402.520.000 |
| 2000 | 817.000 | 2.500.000 | 65.400.000 | 386.400.000 | 455.117.000 |
| 2001 | 920.000 | 3.350.000 | 73.600.000 | 390.000.000 | 467.870.000 |
| 2002 | 1.050.000 | 3.670.000 | 75.000.000 | 442.200.000 | 521.920.000 |
| 2003 | 1.184.000 | 3.860.000 | 77.400.000 | 492.000.000 | 574.444.000 |
| 2004 | 1.231.000 | 4.200.000 | 78.900.000 | 508.200.000 | 592.531.000 |
| 2005 | 1.281.000 | 5.435.000 | 79.300.000 | 551.520.000 | 637.536.000 |
| 2006 | 1.490.000 | 6.170.000 | 80.300.000 | 589.200.000 | 677.160.000 |
| 2007 | 1.549.000 | 6.945.000 | 83.000.000 | 633.000.000 | 724.494.000 |
| 2008 | 1.754.000 | 7.750.000 | 89.700.000 | 669.600.000 | 768.804.000 |
| 2009 | 1.812.000 | 8.635.000 | 94.850.000 | 698.400.000 | 803.697.000 |
| 2010 | 1.935.000 | 9.456.000 | 98.400.000 | 763.200.000 | 872.991.000 |
| 2011 | 2.045.000 | 10.300.000 | 103.200.000 | 811.200.000 | 926.745.000 |
| 2012 | 2.170.000 | 10.750.000 | 107.400.000 | 838.960.000 | 959.280.000 |
| 2013 | 2.280.000 | 10.850.000 | 109.000.000 | 858.500.000 | 980.630.000 |
| 2014 | 2.490.000 | 11.050.000 | 109.750.000 | 841.800.000 | 965.090.000 |
| 2015 | 2.600.000 | 11.300.000 | 110.120.000 | 819.600.000 | 943.620.000 |

### *5.3. Calculation of Down Time Cost*

Down Time represents a loss of machine opportunity to operate because the machine is damaged or is being repaired. The cost of down time is calculated based on the machine repair hour per year divided by the normal machine working hours per year multiplied by the operator's cost each year.

Normal working hours per year is 4500 hours, calculated based on normal working hours 15 hours / day multiplied by 1 year of work (300 working days).

The calculation of down time costs is calculated by the equation:

Bd = jr / jk x BO

Where :

Bd = Down time cost

jr = Hour of reparations per year

jk = normal machine working hours per year

BO = Maintenance Fee

### *5.4. The Calculation of Average Annual Cost*

The calculation of the average annual cost of Boiler machines includes the average annual downtime cost as shown in Table 3, the average annual operating costs as in Table 4 and capital recovery.

**Table 3:** Cost Calculation of Down Time Boiler Machine

| Year | Hours of improvement per year (Hours) | Normal working hours per year (Hours) | The cost of Maintenance per year (Rp) | The cost of downtime per year (Rp) |
|---|---|---|---|---|
| 1996 | 146 | 4500 | 1.160.000 | 37.636 |
| 1997 | 152 | 4500 | 1.670.000 | 56.409 |
| 1998 | 168 | 4500 | 2.345.000 | 87.547 |
| 1999 | 180 | 4500 | 2.920.000 | 116.800 |
| 2000 | 204 | 4500 | 3.317.000 | 150.371 |
| 2001 | 218 | 4500 | 4.270.000 | 206.858 |
| 2002 | 248 | 4500 | 4.720.000 | 260.124 |
| 2003 | 262 | 4500 | 5.044.000 | 293.673 |
| 2004 | 274 | 4500 | 5.431.000 | 330.688 |
| 2005 | 288 | 4500 | 6.716.000 | 429.824 |
| 2006 | 296 | 4500 | 7.660.000 | 503.858 |
| 2007 | 304 | 4500 | 8.494.000 | 573.817 |
| 2008 | 316 | 4500 | 9.504.000 | 667.392 |
| 2009 | 310 | 4500 | 10.447.000 | 719.682 |
| 2010 | 300 | 4500 | 11.391.000 | 759.400 |
| 2011 | 296 | 4500 | 12.345.000 | 812.027 |
| 2012 | 305 | 4500 | 12.920.000 | 875.689 |
| 2013 | 335 | 4500 | 13.130.000 | 977.456 |
| 2014 | 310 | 4500 | 13.540.000 | 932.756 |
| 2015 | 295 | 4500 | 13.900.000 | 911.222 |

### *5.5. The Average Calculation of Down Time Annual Cost*

**Table 4:** Calculation of the average annual Down Time cost of the Boiler engine

| **Year** | **Cost of Down Time Per Year (Rp)** | **Present Worth Factor (P/F, 6%,n)** | **P.V Cost of Down Time (Rp)** | **∑ P.V Cost of Down Time (Rp)** | **Capital Recovery Factor (A/P, 6%,n)** | **Average of Down Time Cost (Rp)** |
|---|---|---|---|---|---|---|
| 1996 | 37.636 | 0.9434 | 35.504 | 35.504 | 1.06 | 37.634 |
| 1997 | 56.409 | 0.8900 | 50.203 | 85.707 | 0.5454 | 46.745 |
| 1998 | 87.547 | 0.8396 | 73.503 | 159.210 | 0.3741 | 59.560 |
| 1999 | 116.800 | 0.7921 | 92.517 | 251.727 | 0.2886 | 72.648 |
| 2000 | 150.371 | 0.7473 | 112.371 | 364.098 | 0.2374 | 86.437 |
| 2001 | 206.858 | 0.7050 | 145.834 | 509.932 | 0.2034 | 103.720 |
| 2002 | 260.124 | 0.6651 | 173.008 | 682.940 | 0.1791 | 122.315 |
| 2003 | 293.673 | 0.6274 | 184.249 | 867.189 | 0.1610 | 139.617 |
| 2004 | 330.688 | 0.5919 | 195.733 | 1.062.922 | 0.1470 | 156.250 |
| 2005 | 429.824 | 0.5584 | 240.013 | 1.302.935 | 0.1359 | 177.069 |
| 2006 | 503.858 | 0.5268 | 265.431 | 1.568.366 | 0.1268 | 198.869 |
| 2007 | 573.817 | 0.4970 | 285.186 | 1.853.552 | 0.1193 | 221.129 |
| 2008 | 667.392 | 0.4688 | 312.873 | 2.166.425 | 0.1130 | 244.806 |
| 2009 | 719.682 | 0.4423 | 318.315 | 2.484.740 | 0.1076 | 267.358 |
| 2010 | 759.400 | 0.4173 | 316.897 | 2.801.637 | 0.1030 | 288.569 |
| 2011 | 812.027 | 0.3936 | 319.613 | 3.121.250 | 0.0990 | 309.004 |
| 2012 | 875.689 | 0.3714 | 325.230 | 3.446.480 | 0.0954 | 328.794 |
| 2013 | 977.456 | 0.3503 | 342.402 | 3.788.882 | 0.0924 | 350.093 |
| 2014 | 932.756 | 0.3305 | 308.275 | 4.097.157 | 0.0896 | 367.105 |
| 2015 | 911.222 | 0.3118 | 284.119 | 4.381.276 | 0.0872 | 382.047 |

a. Average of Annual Operating Cost

Calculation of the average annual operating cost of boiler machine can be seen in table 5 below.

**Table 5:** Average Calculation of Annual Operating Cost of Boiler Machine

| Year | Operating Cost Per Year (Rp) | Present Worth Factor (P/F, 6%,n) | P.V Cost Of Operation (Rp) | ∑ P.V Cost Of Operation (Rp) | Capital Recovery Factor (A/P, 6%,n) | Average Cost of Annual Operating (Rp) |
|---|---|---|---|---|---|---|
| 1996 | 303.960.000 | 0.9434 | 286.755.864 | 286.755.864 | 1.06 | 303.961.216 |
| 1997 | 367.970.000 | 0.8900 | 327.493.300 | 614.249.164 | 0.5454 | 335.011.494 |
| 1998 | 389.905.000 | 0.8396 | 327.364.238 | 941.613.402 | 0.3741 | 352.257.574 |
| 1999 | 402.520.000 | 0.7921 | 318.836.092 | 126.0449.494 | 0.2886 | 363.765.724 |
| 2000 | 455.117.000 | 0.7473 | 340.108.934 | 160.055.8428 | 0.2374 | 379.972.571 |
| 2001 | 467.870.000 | 0.7050 | 329.848.350 | 193.0406.778 | 0.2034 | 392.644.739 |
| 2002 | 521.920.000 | 0.6651 | 347.128.992 | 2.277.535.770 | 0.1791 | 407.906.656 |
| 2003 | 574.444.000 | 0.6274 | 360.406.165 | 2.637.941.936 | 0.1610 | 424.708.652 |
| 2004 | 592.531.000 | 0.5919 | 350.719.098 | 2.988.661.035 | 0.1470 | 439.333.172 |
| 2005 | 637.536.000 | 0.5584 | 356.000.102 | 3.344.661.137 | 0.1359 | 454.539.449 |
| 2006 | 677.160.000 | 0.5268 | 356.727.888 | 3.701.389.025 | 0.1268 | 469.336.128 |
| 2007 | 724.494.000 | 0.4970 | 360.073.518 | 4.061.462.543 | 0.1193 | 484.532.481 |
| 2008 | 768.804.000 | 0.4688 | 360.415.315 | 4.421.877858 | 0.1130 | 499.672.198 |
| 2009 | 803.697.000 | 0.4423 | 355.475.183 | 4.777.353041 | 0.1076 | 514.043.187 |
| 2010 | 872.991.000 | 0.4173 | 364.299.144 | 5.141.652.186 | 0.1030 | 529.590.175 |
| 2011 | 926.745.000 | 0.3936 | 364.766.832 | 5.506.419.018 | 0.0990 | 545.135.483 |
| 2012 | 959.280.000 | 0.3714 | 356.276.592 | 5.862.695.610 | 0.0954 | 559.301.161 |
| 2013 | 980.630.000 | 0.3503 | 343.514.689 | 6.206.210.299 | 0.0924 | 573.453.832 |
| 2014 | 965.090.000 | 0.3305 | 318.962.245 | 6.525.172.544 | 0.0896 | 584.655.460 |
| 2015 | 943.620.000 | 0.3118 | 294.220.716 | 6.819.393.260 | 0.0872 | 594.651.092 |

b. Total Average of Annual Cost

Total average annual cost is calculated by the formula:

Total average annual cost = Capital Recovery (CR) + average annual operating cost + average annual down time cost. Annual Cost Calculation The average Sheeter machine can be seen in Table 6 below.

**Table 6:** Calculation of Total Average Boiler Annual Costs

| Year | Average Cost of Annual Operating (Rp) | Average Cost of annual Down Time (Rp) | *Capital Recovery* (Rp) | Average Cost of Total Annual (Rp) |
|---|---|---|---|---|
| 1996 | 303.961.216 | 37.634 | 721.000.000 | 1.024.998.850 |
| 1997 | 335.011.494 | 46.745 | 692.970.816 | 1.028.029.055 |
| 1998 | 352.257.574 | 59.560 | 666.997.611 | 1.019.314.745 |
| 1999 | 363.765.724 | 72.648 | 642.887.732 | 1.006.726.104 |
| 2000 | 379.972.571 | 86.437 | 620.466.530 | 1.000.525.538 |
| 2001 | 392.644.739 | 103.720 | 599.710.768 | 992.459.227 |
| 2002 | 407.906.656 | 122.315 | 580.201.419 | 988.230.390 |
| 2003 | 424.708.652 | 139.617 | 562.199.203 | 987.047.472 |
| 2004 | 439.333.172 | 156.250 | 545.498.101 | 984.987.523 |
| 2005 | 454.539.449 | 177.069 | 530.089.069 | 984.805.587 |
| 2006 | 469.336.128 | 198.869 | 515.536.749 | 985.071.746 |
| 2007 | 484.532.481 | 221.129 | 502.111.524 | 986.865.134 |
| 2008 | 499.672.198 | 244.806 | 489.623.823 | 989.540.827 |
| 2009 | 514.043.187 | 267.358 | 477.854.190 | 992.164.735 |
| 2010 | 529.590.175 | 288.569 | 467.049.440 | 996.928.184 |
| 2011 | 545.135.483 | 309.004 | 456.947.393 | 1.002.391.880 |
| 2012 | 559.301.161 | 328.794 | 447.132.254 | 1.006.762.209 |
| 2013 | 573.453.832 | 350.093 | 438.660.840 | 1.012.464.765 |
| 2014 | 584.655.460 | 367.105 | 430.174.336 | 1.015.196.901 |
| 2015 | 594.651.092 | 382.047 | 422.647.838 | 1.017.680.977 |

### *5.6. Forecasting*

Operating cost calculation is obtained from sum of lubricant usage cost, spare part cost, fuel cost. The calculation of boiler machine operating costs can be seen in Table 7 below.

a. Calculation of Forecasting Operating Costs

For the calculation of boiler operating cost forecasting parameters from 2016-2020 consist of calculation of fuel cost forecasting, spare parts cost and lubricant cost in Table 8 below.

**Table 7:** Calculation of Operating Cost of Boiler Machine

| Year | Lubricant cost per year | Spare parts cost per year | Fuel costs per year | Operator wages per year | Operating cost per year |
|---|---|---|---|---|---|
| 1996 | 440.000 | 720.000 | 33.400.000 | 269.400.000 | 303.960.000 |
| 1997 | 500.000 | 1.170.000 | 38.700.000 | 327.600.000 | 367.970.000 |
| 1998 | 620.000 | 1.725.000 | 42.200.000 | 345.360.000 | 389.905.000 |
| 1999 | 700.000 | 2.220.000 | 54.000.000 | 345.600.000 | 402.520.000 |
| 2000 | 817.000 | 2.500.000 | 65.400.000 | 386.400.000 | 455.117.000 |
| 2001 | 920.000 | 3.350.000 | 73.600.000 | 390.000.000 | 467.870.000 |
| 2002 | 1.050.000 | 3.670.000 | 75.000.000 | 442.200.000 | 521.920.000 |
| 2003 | 1.184.000 | 3.860.000 | 77.400.000 | 492.000.000 | 574.444.000 |
| 2004 | 1.231.000 | 4.200.000 | 78.900.000 | 508.200.000 | 592.531.000 |
| 2005 | 1.281.000 | 5.435.000 | 79.300.000 | 551.520.000 | 637.536.000 |
| 2006 | 1.490.000 | 6.170.000 | 80.300.000 | 589.200.000 | 677.160.000 |
| 2007 | 1.549.000 | 6.945.000 | 83.000.000 | 633.000.000 | 724.494.000 |
| 2008 | 1.754.000 | 7.750.000 | 89.700.000 | 669.600.000 | 768.804.000 |
| 2009 | 1.812.000 | 8.635.000 | 94.850.000 | 698.400.000 | 803.697.000 |
| 2010 | 1.935.000 | 9.456.000 | 98.400.000 | 763.200.000 | 872.991.000 |
| 2011 | 2.045.000 | 10.300.000 | 103.200.000 | 811.200.000 | 926.745.000 |
| 2012 | 2.170.000 | 10.750.000 | 107.400.000 | 838.960.000 | 959.280.000 |
| 2013 | 2.280.000 | 10.850.000 | 109.000.000 | 858.500.000 | 980.630.000 |
| 2014 | 2.490.000 | 11.050.000 | 109.750.000 | 841.800.000 | 965.090.000 |
| 2015 | 2.600.000 | 11.300.000 | 110.120.000 | 819.600.000 | 943.620.000 |

$a = \frac{\sum y}{n}$ $\quad$ $a = \frac{1.603.620.000}{20} = 80.181.000$

$b = \frac{\sum xy}{\sum x^2}$ $\quad$ $b = \frac{1.805.430.000}{670} = 2.694.672,642$

**Y = 80.181.000 + 2.694.672,642 (x)**

**Calculation of Spare Parts Forecasting Parameters**

$a = \frac{\sum y}{n}$ $\quad$ $a = \frac{122.056.000}{20} = 6.102.800$

$b = \frac{\sum xy}{\sum x^2}$ $\quad$ $b = \frac{349.309.000}{670} = 521.356,716$

**Y = 6.102.800 + 521.356,716 (x)**

**Table 8:** Calculation of Fuel Cost Forecasting Parameters

| **Year** | **Period (x)** | **Cost Y (Rp)** | **xY (Rp)** | **$x^2$** |
|---|---|---|---|---|
| 1996 | -10 | 33.400.000 | 334.000.000 | 81 |
| 1997 | -9 | 38.700.000 | 348.300.000 | 64 |
| 1998 | -8 | 42.200.000 | 337.600.000 | 49 |
| 1999 | -7 | 54.000.000 | 378.000.000 | 36 |
| 2000 | -6 | 65.400.000 | 392.400.000 | 25 |
| 2001 | -5 | 73.600.000 | 368.000.000 | 16 |
| 2002 | -4 | 75.000.000 | 300.000.000 | 9 |
| 2003 | -3 | 77.400.000 | 232.200.000 | 4 |
| 2004 | -2 | 78.900.000 | 157.800.000 | 1 |
| 2005 | -1 | 79.300.000 | 79.300.000 | 0 |
| 2006 | 0 | 80.300.000 | - | 1 |
| 2007 | 1 | 83.000.000 | 83.000.000 | 4 |
| 2008 | 2 | 89.700.000 | 179.400.000 | 9 |
| 2009 | 3 | 94.850.000 | 284.550.000 | 16 |
| 2010 | 4 | 98.400.000 | 393.600.000 | 25 |
| 2011 | 5 | 103.200.000 | 516.000.000 | 36 |
| 2012 | 6 | 107.400.000 | 644.400.000 | 49 |
| 2013 | 7 | 109.000.000 | 763.000.000 | 64 |
| 2014 | 8 | 109.750.000 | 878.000.000 | 81 |
| 2015 | 9 | 110.120.000 | 991.080.000 | 100 |
| **Total ∑** | | **1.603.620.000** | **1.805.430.000** | **670** |

**Calculation of Forecasting Parameters of Lubricant Usage Cost**

$a = \frac{\sum y}{n}$ $\quad$ $a = \frac{28.868.000}{20} = 1.443.400$

$b = \frac{\sum xy}{\sum x^2}$ $\quad$ $b = \frac{61.001.000}{670} = 91.046,268$

**Yt = 1.443.400 + 134.132,835 (x)**

**Calculation of Operator Wage Forecasting Parameters**

$a = \frac{\sum y}{n}$ $a = \frac{11.581.740.000}{20} = 579.087.000$

$b = \frac{\sum xy}{\sum x^2}$ $b = \frac{16.424.660.000}{670} = 24.514.417,91$

**Yt = 579.087.000 + 24.514.417,91 (x)**

**Cost Forecasting Calculation of Down Time**

For the calculation of Cost Forecasting parameters of Down Time Boiler from 2016-2020 can be seen in Table 9 below.

**Table 9:** Calculation of Down Time Cost Forecasting

| **Year** | **x** | **Y (Rp)** | **xY (Rp)** | **$x^2$** | **$x^2$Y (Rp)** | **$x^4$** |
|---|---|---|---|---|---|---|
| 1996 | -10 | 37.636 | (376.360) | 100 | 3.763.600 | 10.000 |
| 1997 | -9 | 56.409 | (507.681) | 81 | 4.569.129 | 6.561 |
| 1998 | -8 | 87.547 | (700.376) | 64 | 5.603.008 | 4.096 |
| 1999 | -7 | 116.800 | (817.600) | 49 | 5.723.200 | 2.401 |
| 2000 | -6 | 150.371 | (902.226) | 36 | 5.413.356 | 1.296 |
| 2001 | -5 | 206.858 | (1.034.290) | 25 | 5.171.450 | 625 |
| 2002 | -4 | 260.124 | (1.040.496) | 16 | 4.161.984 | 256 |
| 2003 | -3 | 293.673 | (881.019) | 9 | 2.643.057 | 81 |
| 2004 | -2 | 330.688 | (661.376) | 4 | 1.322.752 | 16 |
| 2005 | -1 | 429.824 | (429.824) | 1 | 429.824 | 1 |
| 2006 | 0 | 503.858 | - | - | - | - |
| 2007 | 1 | 573.817 | 573.817 | 1 | 573.817 | 1 |
| 2008 | 2 | 667.392 | 1.334.784 | 4 | 2.669.568 | 16 |
| 2009 | 3 | 719.682 | 2.159.046 | 9 | 6.477.138 | 81 |
| 2010 | 4 | 759.400 | 3.037.600 | 16 | 12.150.400 | 256 |
| 2011 | 5 | 812.027 | 4.060.135 | 25 | 20.300.675 | 625 |
| 2012 | 6 | 875.689 | 5.254.134 | 36 | 31.524.804 | 1.296 |
| 2013 | 7 | 977.456 | 6.842.192 | 49 | 47.895.344 | 2.401 |
| 2014 | 8 | 932.756 | 7.462.048 | 64 | 59.696.384 | 4.096 |
| 2015 | 9 | 911.222 | 8.200.998 | 81 | 73.808.982 | 6.561 |
| **Jumlah∑** | **10** | **9.703.229** | **31.573.506** | **670** | **293.898.472** | **40.666** |

$b = \frac{\sum xY}{\sum x^2}$ $b = \frac{31.573.506}{670} = 47.124,63$

$c = \frac{n \sum x^2 Y - \sum x^2 \sum Y}{n \sum X4 - (\sum x^2)^2}$ $c = \frac{20(293.898.472) - (670)(9.703.229)}{20(40.666) - (670)^2} = 1.710,098$

$a = \frac{\sum Y - c \sum x^2}{n}$ $a = \frac{9.703.229 - 1.710,098\ (670)}{20} = 427.873,16$

**Y = 427.873,16 + 47.124,63(x) + 1.710,098$(x)^2$**

Average Annual downtime fee (2016-2020)

The calculation result of annual down time cost of boiler machine average can be seen in table 10 below.

**Table 10:** Calculation of Down Time Average Cost of Boiler

| **Year** | **Cost of Down Time Per Year (Rp)** | **Present Worth Factor (P/F, 6%,n)** | **P.V Cost of Down Time (Rp)** | **∑ P.V Cost of Down Time (Rp)** | **Capital Recovery Factor (A/P, 6%,n)** | **The Average Cost of Down Time (Rp)** |
|---|---|---|---|---|---|---|
| 1996 | 37.636 | 0.9434 | 35.504 | 35.504 | 1.06 | 37.634 |
| 1997 | 56.409 | 0.8900 | 50.203 | 85.707 | 0.5454 | 46.745 |
| 1998 | 87.547 | 0.8396 | 73.503 | 159.210 | 0.3741 | 59.560 |
| 1999 | 116.800 | 0.7921 | 92.517 | 251.727 | 0.2886 | 72.648 |
| 2000 | 150.371 | 0.7473 | 112.371 | 364.098 | 0.2374 | 86.437 |
| 2001 | 206.858 | 0.7050 | 145.834 | 509.932 | 0.2034 | 103.720 |
| 2002 | 260.124 | 0.6651 | 173.008 | 682.940 | 0.1791 | 122.315 |
| 2003 | 293.673 | 0.6274 | 184.249 | 867.189 | 0.1610 | 139.617 |
| 2004 | 330.688 | 0.5919 | 195.733 | 1.062.922 | 0.1470 | 156.250 |
| 2005 | 429.824 | 0.5584 | 240.013 | 1.302.935 | 0.1359 | 177.069 |
| 2006 | 503.858 | 0.5268 | 265.431 | 1.568.366 | 0.1268 | 198.869 |
| 2007 | 573.817 | 0.4970 | 285.186 | 1.853.552 | 0.1193 | 221.129 |
| 2008 | 667.392 | 0.4688 | 312.873 | 2.166.425 | 0.1130 | 244.806 |
| 2009 | 719.682 | 0.4423 | 318.315 | 2.484.740 | 0.1076 | 267.358 |
| 2010 | 759.400 | 0.4173 | 316.897 | 2.801.637 | 0.1030 | 288.569 |
| 2011 | 812.027 | 0.3936 | 319.613 | 3.121.250 | 0.0990 | 309.004 |
| 2012<br>2013 | 875.689<br>977.456 | 0.3714<br>0.3503 | 325.230<br>342.402 | 3.446.480<br>3.788.882 | 0.0954<br>0.0924 | 328.794<br>350.093 |
| 2014 | 932.756 | 0.3305 | 308.275 | 4.097.157 | 0.0896 | 367.105 |
| 2015 | 911.222 | 0.3118 | 284.119 | 4.381.276 | 0.0872 | 382.047 |
| 2016 | 2.171.644 | 0.2942 | 638.898 | 5.020.174 | 0.085 | 426.715 |
| 2017 | 2.292.302 | 0.2775 | 636.113 | 5.656.287 | 0.083 | 469.472 |
| 2018 | 2.416.381 | 0.2618 | 632.609 | 6.288.896 | 0.0813 | 511.287 |
| 2019 | 2.543.880 | 0.2470 | 628.338 | 6.917.234 | 0.0797 | 551.304 |
| 2020 | 2.674.800 | 0.2330 | 623.228 | 7.540.462 | 0.0782 | 589.664 |

### *5.7. Average Cost of Annual Operating (Year 2016-2020)*

The calculation of the average annual operating cost of a boiler machine can be seen in the table

**Table 11:** Calculation of Mean Operating Costs of Boiler Average

| Year | Cost Operation Per year (Rp) | Present Worth Factor (P/F, 6%,n) | P.V Cost Operation (Rp) | ∑ P.V Cost Operation (Rp) | Capital Recovery Factor (A/P, 6%,n) | Average Cost of Annual Operating (Rp) |
|---|---|---|---|---|---|---|
| 1996 | 303.960.000 | 0.9434 | 286.755.864 | 286.755.864 | 1.06 | 303.961.216 |
| 1997 | 367.970.000 | 0.8900 | 327.493.300 | 614.249.164 | 0.5454 | 335.011.494 |
| 1998 | 389.905.000 | 0.8396 | 327.364.238 | 941.613.402 | 0.3741 | 352.257.574 |
| 1999 | 402.520.000 | 0.7921 | 318.836.092 | 126.0449.494 | 0.2886 | 363.765.724 |
| 2000 | 455.117.000 | 0.7473 | 340.108.934 | 160.055.8428 | 0.2374 | 379.972.571 |
| 2001 | 467.870.000 | 0.7050 | 329.848.350 | 193.0406.778 | 0.2034 | 392.644.739 |
| 2002 | 521.920.000 | 0.6651 | 347.128.992 | 2.277.535.770 | 0.1791 | 407.906.656 |
| 2003 | 574.444.000 | 0.6274 | 360.406.165 | 2.637.941.936 | 0.1610 | 424.708.652 |
| 2004 | 592.531.000 | 0.5919 | 350.719.098 | 2.988.661.035 | 0.1470 | 439.333.172 |
| 2005 | 637.536.000 | 0.5584 | 356.000.102 | 3.344.661.137 | 0.1359 | 454.539.449 |
| 2006 | 677.160.000 | 0.5268 | 356.727.888 | 3.701.389.025 | 0.1268 | 469.336.128 |
| 2007 | 724.494.000 | 0.4970 | 360.073.518 | 4.061.462.543 | 0.1193 | 484.532.481 |
| 2008 | 768.804.000 | 0.4688 | 360.415.315 | 4.421.877858 | 0.1130 | 499.672.198 |
| 2009 | 803.697.000 | 0.4423 | 355.475.183 | 4.777.353041 | 0.1076 | 514.043.187 |
| 2010 | 872.991.000 | 0.4173 | 364.299.144 | 5.141.652.186 | 0.1030 | 529.590.175 |
| 2011 | 926.745.000 | 0.3936 | 364.766.832 | 5.506.419.018 | 0.0990 | 545.135.483 |
| 2012 | 959.280.000 | 0.3714 | 356.276.592 | 5.862.695.610 | 0.0954 | 559.301.161 |
| 2013 | 980.630.000 | 0.3503 | 343.514.689 | 6.206.210.299 | 0.0924 | 573.453.832 |
| 2014 | 965.090.000 | 0.3305 | 318.962.245 | 6.525.172.544 | 0.0896 | 584.655.460 |
| 2015 | 943.620.000 | 0.3118 | 294.220.716 | 6.819.393.260 | 0.0872 | 594.651.092 |
| 2016 | 1.253.065.553 | 0.2942 | 368.651.886 | 7.188.045.146 | 0.085 | 610.983.837 |
| 2017 | 1.280.887.046 | 0.2775 | 355.446.155 | 7.543.491.301 | 0.083 | 626.109.778 |
| 2018 | 1.308.708.539 | 0.2618 | 342.619.896 | 7.886.111.196 | 0.0813 | 641.140.840 |
| 2019 | 1.336.530.032 | 0.2470 | 330.122.918 | 8.216.234.114 | 0.0797 | 654.833.859 |
| 2020 | 1.364.351.525 | 0.2330 | 317.893.905 | 8.534.128.020 | 0.0782 | 667.368.811 |

### *5.8. Determination of the Economical Age of Boiler Machine*

The economic life of a Boiler machine is a proactive and profitable period of Boiler machine usage. Economic life is earned at the time of the smallest average annual total cost. Calculation of Boiler's average cost of annual can be seen in Table 12 below.

**Table 12:** Calculation of Average Annual Boiler Cost

| **Year** | **Average Cost of Annual Operating (Rp)** | **Average Cost of annual Down Time (Rp)** | ***Capital Recovery*** **(Rp)** | **Total Average Annual Cost (Rp)** |
|---|---|---|---|---|
| 1996 | 303.961.216 | 37.634 | 721.000.000 | 1.024.998.850 |
| 1997 | 335.011.494 | 46.745 | 692.970.816 | 1.028.029.055 |
| 1998 | 352.257.574 | 59.560 | 666.997.611 | 1.019.314.745 |
| 1999 | 363.765.724 | 72.648 | 642.887.732 | 1.006.726.104 |
| 2000 | 379.972.571 | 86.437 | 620.466.530 | 1.000.525.538 |
| 2001 | 392.644.739 | 103.720 | 599.710.768 | 992.459.227 |
| 2002 | 407.906.656 | 122.315 | 580.201.419 | 988.230.390 |
| 2003 | 424.708.652 | 139.617 | 562.199.203 | 987.047.472 |
| 2004 | 439.333.172 | 156.250 | 545.498.101 | 984.987.523 |
| **2005** | **454.539.449** | **177.069** | **530.089.069** | **984.805.587** |
| 2006 | 469.336.128 | 198.869 | 515.536.749 | 985.071.746 |
| 2007 | 484.532.481 | 221.129 | 502.111.524 | 986.865.134 |
| 2008 | 499.672.198 | 244.806 | 489.623.823 | 989.540.827 |
| 2009 | 514.043.187 | 267.358 | 477.854.190 | 992.164.735 |
| 2010 | 529.590.175 | 288.569 | 467.049.440 | 996.928.184 |
| 2011 | 545.135.483 | 309.004 | 456.947.393 | 1.002.391.880 |
| 2012 | 559.301.161 | 328.794 | 447.132.254 | 1.006.762.209 |
| 2013 | 573.453.832 | 350.093 | 438.660.840 | 1.012.464.765 |
| 2014 | 584.655.460 | 367.105 | 430.174.336 | 1.015.196.901 |
| 2015 | 594.651.092 | 382.047 | 422.647.838 | 1.017.680.977 |
| 2016 | 610.983.837 | 426.715 | 415.399.275 | 1.026.809.827 |
| 2017 | 626.109.778 | 469.472 | 408.532.346 | 1.035.138.596 |
| 2018 | 641.140.840 | 511.287 | 402.577.159 | 1.044.229.286 |
| 2019 | 654.833.859 | 551.304 | 396.740.458 | 1.052.125.621 |
| 2020 | 667.368.811 | 589.664 | 391.073.335 | 1.059.031.810 |
| **Total** ∑ | | | | **25.239.526.989** |

From the calculation of the total average annual cost in Table 12, it was that the average annual operating cost, average annual down time cost, and depreciation cost (capital recovery) from 1996 to 2020, so that the Government Plantation Enterprises (PTPN II) Pagar Merbau can determine the total the average annual cost of a Boiler engine.

The company can also pay attention to maintenance (maintenance) boiler machine for maximum production process and profitable for the Government Plantation Enterprises (PTPN II) Pagar Merbau. From the calculation, the average total annual cost of the youngest economic life of boiler in was on the 10th year (2005) since the purchase of Boiler machine (year 1995) of IDR. 984.805.587.

## 6. Conclusion

After the calculation and analysis done, it can be taken a conclusion. The average total annual cost of the youngest economic life of boiler in was on the 10th year (2005) since the purchase of Boiler machine (year 1995The economic life of the boiler engine is found in the 10th year found in 2005.

Total average annual cost of boiler engine minimum was IDR. 984.805.587. The total annual cost of the average maximum boiler engine was IDR 1.059.031.810

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