A Goal Programming Model for Solving Renewable Energy Planning Problem Generated from Palm Oil Waste

Syamsul Amien¹, Setiaty Pandia¹, Herman Mawengkang¹, Harmein Nasution¹
¹ Universitas Sumatera Utara, Medan - Indonesia
* hmawengkang@yahoo.com*

Abstract. It is widely acknowledged that energy plays central role to achieving goals of modern society. Many developing countries face population growth that far exceeds planned rates of grid connection, so that many will either remain without energy, or be forced to migrate to urban areas where the infrastructure is already over burdened. However, nowadays the world is plague with global warming problem due to the energy inefficiencies. This paper describes a plan about how to get renewable energy from the processed whole waste of oil palm. As there are three objectives should be fulfilled, we model the plan using multi-objective programs. The result shows that it is possible to get optimal energy while minimizing the waste created from oil palm.

1. Introduction

Energy is a master resource (the master resource), the ultimate raw material is a vital part to support the life of creatures in nature. Energy also plays an important role in the social and economic development of a country. Population growth has exceeded the existing energy planning, resulting in urbanization and people will be competing to create renewable energy as a solution in dealing with the thinning of primary (non-renewable) energy such as petroleum, coal and natural gas. Constraints of new renewable energy are high investment costs and low power that can be generated / obtained, but because energy needs continue to increase, palm oil waste is quite effective as a substitute for nonrenewable energy. However, palm waste will have a negative impact on the environment if left unchecked, because the decomposition process produces methane (CH4) as a cause of global warming. In order for its utilization to be optimal, it is necessary to design models involving a balance of ecological, social, technical and economic aspects. This balance is critical to the preservation of nature and the prosperity of the country due to the many energy needs, so that its use must be as effective as possible. [1], [2]. This research focuses on renewable energy from the biomass of palm oil waste, because Indonesia is the largest CPO producer in the world. Technological advancement is not only to reduce environmental pollution, but to make palm oil waste as fuel, which means we have joined the energy generation for future generations. The results of the research data, for an PKS with a capacity of 100,000 tons of fresh fruit bunches (FFB) per year will produce 6 thousand tons of shells, 12 thousand tons of fibers and 23 thousand tons of empty fruit bunches (TBK). In its use, fibers and shells can be used / burned directly, while TBK must be dried without direct sunlight. [3]. "A Goal Programming Model for Solving Renewable Energy Planning Problem Generated from Palm Oil Waste" is a design of utilization of biomass solid palm waste (shells, fibers, empty bunches, pome sludge, leaf midrib and tree trunks) which are integrated to obtain optimal utilization. The measurement of energy for each type of waste is carried out at the Department of Industry, Department of Industry, Sei Mangke, North Sumatra This research is an optimal energy planning,
where there are two objectives that are related but mutually conflicting, namely maximizing energy and minimizing pollution [4].

The flow of palm oil waste energy utilization process can be described as follows:

![Diagram of Utilization of Palm Oil Waste](image)

**Figure 1.** Diagram of Utilization of Palm Oil Waste.

1.1. **Research Purposes**
   a. Make a model for using palm waste to obtain optimal energy.
   b. Make a model for using palm waste to obtain optimal energy.

1.2. **Research Hypothesis**
   a. Mixing of integrated palm waste, will determine the optimal value of using waste in generating energy and reducing pollution to the environment.
   b. The amount of calories produced is decent renewable energy as a substitute for non-renewable energy.

1.3. **Novelty of Research**
   a. Integrated use planning model of all palm waste to minimize environmental pollution and obtain optimal energy.
   b. Determine the economic value of the integrated utilization of all palm oil waste for energy.

2. **Methodology**

2.1. **Utilization of Palm Oil Waste as Renewable Energy.**

The waste produced by the Palm Oil Mill (PKS) in the form of shells, fruit fibers, empty bunches, pome sludge and waste from oil palm plants, namely leaf midribs and tree trunks is quite a lot of renewable energy sources in Indonesia. If the waste is not used, it will pollute the environment, such as global warming because it produces CH4, CO and CO2 and NH4 gas. Waste produced by Palm Oil Mill (POM) in the form of shells, fibers, empty bunch and sludge. The scientific journal "Nature Climate Change", by Philip G. Taylor of the University of Colorado, states that 115 million tons of CO, in Malaysia and Indonesia alone can raise the temperature of 1% of global GHG emissions by 2050. CH4 palm oil can represent 15% of GHG emissions in the forestry sector, and 1 ton of CH4 will equal 24 tons of CO2 equivalent. Palm waste has a considerable energy content. Therefore, palm oil waste needs to be used to be used as renewable energy [5].
2.2. Environmental Pollution

Besides being positive for energy, it turns out that palm oil waste also has a negative impact on the environment, because it can contaminate environmental elements of water, soil and air. **Liquid waste**, pome from PKS ranges (50-65)% namely condensate waste water (9-15)% and treated water (35-50)%. The content of BOD = 250 ppm, pH = 6-9, COD = 500 ppm, total suspended solid (TSS) = 300 ppm, NH3 - N = 20 ppm and oil grease = 30 ppm also NH4 gas causes bad odor [6]. **Solid waste** produced by PKS consists of shells (6-9)%, fibers (10-12)%, empty bunches (20-23)%, and pome (sludge) deposits (10-20)%, then solid waste from plantations in the form of leaf midribs and tree trunks. **Gas waste**, from palm waste in the form of CO, CO2, CH4 and others, causes of air pollution and global warming. Air pollution is a very serious problem because it is a basic element that directly affects human health and can also disrupt the balance of nature, especially the Earth's atmosphere.

2.3. Basic Model Framework for mixing palm oil waste.

Research to describe the mixture of all solid palm waste, with two objectives in mutually conflicting unity which is minimizing pollution and producing optimal energy, with a multi-objective program model (MOP) [7]. In general, the form of multi-objective program models can be written as follows:

Maximize/minimize \{F_1(x), F_2(x), \ldots, F_k(x)\} \tag{1}

With constraints \quad Ax = b \tag{2}

\quad x \geq 0 \tag{3}

Or expressed in mathematical form as follows:

Maximize (calori) \quad F_1(x_1, x_2, \ldots, x_6) \tag{4}

Minimize (pollutions) \quad F_2(x_1, x_2, \ldots, x_6) \tag{5}

\begin{align*}
& g_1(x_1, \ldots, x_4) \leq TBS \\
& \text{availability} \\
& \begin{cases}
& g_2(x_5, x_6) \leq \text{number of palm trees} \\
& \text{With constraints :} \\
& x_1, \ldots, x_6 \geq 0
\end{cases} \tag{6}
\end{align*}

Whereas to determine the amount of process costs stated by:

Process costs, \quad g_3(x_1, x_2, \ldots, x_6) \leq \text{Available capital} \tag{7}

\quad x_1, \ldots, x_6 \geq 0 \tag{8}

With the known amount of calories contained in each type of waste, it will determine the amount of waste mixed in order to obtain optimal energy. All of this is calculated using the Lindo programming liner and manual calculations.

2.4. Availability of Palm Waste Resources

The research location is the SeiMangke Special Economic Zone, North Sumatra with PTPN3's oil palm and PKS sources. The area of oil palm plantations is approximately 21,000 Ha with an average harvest of 2 tons / Ha per two weeks.

| No. | Waste        | Available amount (ton/day) |
|-----|--------------|---------------------------|
| 1.  | Sheel        | 24                        |
| 2.  | Fiber        | 48                        |
| 3.  | Empty bunch  | 92                        |
| 4.  | Sludge of pome| 78                        |
| 5.  | Mildrib      | 675                       |
| 6.  | Tree trunk   | 180                       |

2.5. Research Design
The optimization model used is a multi-objective program model (PMO) or multi-criteria programming (MKP), which can be expressed in mathematical expressions namely:

Maximize, \[ f_h(x), h \in K \] (9)

With constraints, \[ x \in X = \{x \mid Ax \leq b, x \in [0,r]\} \] (10)

Where \( h = \{1,2, \ldots, K\} \) number of functions, \( A \) is coefficient matrix of constraints and \( b \) is a right segment vector, known data \( b \in R^m \). \( f_h(x), h \in K \), is a linear function of the decision variable \( x \), and \( r \) is the upper limit given to \( x \).

2.6. Goal Programming (GP)

Goal Programming (GP) is an important part in the optimization of the Programming Model Optimization (PMO), because through GP the PMO problem can be more easily solved. If the objective has a negative deviation (not achieved target) then has a positive deviation, beyond the goal, then the GP mathematical formulation can be written:

Minimum \[ \sum_{i=1}^{h} P_i(d_i^+, d_i^-) \] (11)

With constraints \[ f_i(x) + d_i^- - d_i^+ = b_i, i = 1, \ldots , h \] (12)

\[ x \in x \] (13)

\[ d_i^+, d_i^- = 0 , i = 1, \ldots , h \] (14)

\[ d_i^+, d_i^- \geq 0 , i = 1, \ldots , h \] (15)

This GP model is converted to a GP model with priority, with the form of the objective function:

Minimum \[ \sum_{i=1}^{h} P_i(d_i^+, d_i^-) \] (16)

\( P_i \) state the priority order of each target. The objective of GP is to measure the minimization of the target's unwanted deviation. From the point of view of the objective function and the determined private GP, it is divided into two variants [8].

With first priority, \( P_1 \): meminimize environmental pollution

While the second priority, \( P_2 \): memaximize acquisition calories (energy).

And the third priority, \( P_3 \): meminimize total cost.

Mathematically lexicographic GP can be expressed in the following general form:

Minimum \[ Q = \sum_{i=1}^{m} P_i(d_i^+ + d_i^-) \] (17)

With Target constraints \[ \sum_{j=1}^{n} a_{ij}x_j = d_i^+ + d_i^- = b_i, \text{ for } i = 1 \ldots m \] (18)

System constraints \[ \sum_{j=1}^{n} a_{ij}x_j = b_i , \text{ for } i = m + 1, \ldots , m + k \] (19)

and \[ d_i^+, d_i^-, x_j \geq 0 \text{ for } i = 1, \ldots , m \]

\[ j = 1, \ldots , n \] (20)

3. Results and Discussion

Table 2. Measuring results data for each type of waste as follows:

| No. | Sample Code | Measuring results of calorioeach waste in Kcal/Kg |
|-----|-------------|-----------------------------------------------|
|     |             | Shell Fiber Empty Bunch Meldrib Tree Trunk Sludge |
| 1.  | x1          | 4300   3495   4150   3625   4030   2850 |
| 2.  | x2          | 4250   3450   4090   3720   3900   2830 |
| 3.  | x3          | 4350   3435   4250   3675   4100   2805 |
| 4.  | x4          | 4400   3475   4055   3757   3985   2780 |
| 5.  | x5          | 4450   3455   4000   3724   4200   2765 |

3.1. Optimization Model

Complete description of the Goal Programming Model, is expressed as:

Priority I, minimizing pollution with objective function \( P_1(d_1^-) \),

Priority II, maximizing energy \( P_2(d_2^+) \).
Completely: Minimize $Z = P_1(d_1^+ + d_1^-) + P_2(d_2^+ - d_2^-)$, With constraints:

Waste: $20X_1 + 40X_2 + 80X_3 + 50X_4 + 400X_5 + 100X_6 = d_1^+ + d_1^- = \text{target (ton/day)}$  
Energy: $4350X_1 + 3462X_2 + 4109X_3 + 2806X_4 + 3700X_5 + 4022X_6 = d_2^+ + d_2^- = \text{target (calories)}$

System constraints: $X_1 + X_2 + X_3 + X_4 \leq 400$ (total FFB used in ton/day)  
$X_5 + X_6 \leq 2,500,000$ (number of oil palm tree)

$C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4 + C_5X_5 + C_6X_6 \leq \text{collection and transportation costs.}$  
$C_7X_1 + C_8X_2 + C_9X_3 + C_{10}X_4 + C_{11}X_5 + C_{12}X_6 \leq \text{waste processing costs.}$  
$C_{13}(X_1 + X_2 + X_3 + X_4 + X_5 + X_6) \leq \text{cost of the integration process.}$  
$X_1, X_2, X_3, X_4, X_5, X_6, d_1^+, d_1^-, d_2^+, d_2^- \geq 0$

Where $C_1, C_2, \ldots \ldots C_6$ are collection and transportation of each waste, $C_7, C_8, \ldots \ldots C_{12}$ = the processing cost of each waste, and $C_{13}$ = cost of the mixing process

| No. | Type of waste     | Energy (Kcal/Kg) | Mixed quantity (%) | Mixed Energy (Kcal/Kg) |
|-----|-------------------|------------------|--------------------|------------------------|
| 1.  | Shell             | 4350             | 3,84               |                        |
| 2.  | Fiber             | 3462             | 7,70               |                        |
| 3.  | Empty bunch (EB)  | 4109             | 15,38              |                        |
| 4.  | Sludge of Pome    | 2806             | 7,70               |                        |
| 5.  | Mildrib           | 3700             | 46,15              |                        |
| 6.  | Tree Trunk        | 4022             | 19,23              |                        |
|     | **Total**         | **100,00**       |                    | **3780**               |

The final energy contained in the integrated mixture is equal to, 3780 Kcal/Kg.

![Figure 2. Graph of Calorie Measurement result](image)

3.2. Economic value.

For the production process will neds the cost. Data regarding the gas contained in each palm oil waste can change, because it also depends on the length of the stored waste. For example, CO gas can decrease, but the amount of CH$_4$ gas can increase. From the Lindo program optimization, it was found that the amount of the waste calories was 3945 Kcal/kg. Whereas the measurement results for mixed waste is 3780 Kcal/kg.

This means the difference between the tar (3945-3780) = 165 Kcal/kg, or a deviation of 165/3945 = 4.18%, which is still within tolerance. This difference can occur due to the chemical reaction process in mixing waste, homogeneity of the results of mixing the waste, the combustion process and the tolerance of the use of measuring instruments. Whereas to determine the equivalent electrical power produced, the lowest calorific value of 3780 Kcal/kg was taken, with an integrated total weight of 260
tons/day = 260/24 = 10.83 tons/hour. Then the total calories that can be obtained is 10.830 x 3780 = 40,937,400 Kcal/hour. If this result is transformed into electrical energy it will be equivalent to 40,937.106 x 1,163 = 47,61 MWh. Turbine and Generat or efficiency is taken by 0.7. Then the resulting output becomes 0.7x0.7x47.61 = 23.33 MWh. The selling value of electricity is Rp. 1000 x 23.33 = Rp. 23,330,000/hour for a power plant. While the total cost of processing and transportation of waste raw materials is Rp. 360,000,000/day, or 360,000,000/24 = Rp. 15,000,000/hr. If the tolerance reaches 5%, then the total capital becomes 1.05 x Rp. 15,000,000 = Rp. 15,750,000/hour, or profit Rp. 23,330,000 - Rp. 15,750,000 = Rp. 7,580,000/hour. So that in total it can be said that the profit is (7.58 / 15.75) x 100% = 48.13%. Although the profit is relatively small, but for the future prospects will be better and increased, in line with the need for energy and reducing pollution [8], as well as the need to reduce the use of unrenewable energy such as fuel, natural gas and coal. By utilizing palm oil waste, it can reduce environmental pollution so that it binds to the principle in realizing sustainable and environmentally sound development [9].

4. Conclusion
The conclusions of this article include: Utilization of palm oil waste to energy simultaneously reduce pollution. There is a lot of oil palm biomass in Indonesia, so it needs to be utilized to help domestic energy needs. This optimal utilization is carried out by integrating all solid palm waste, through a multi objective mathematical model. From this integration produced the fuel for various purposes. The environmental pollution reduction can reach 30%, this is obtained from several secondary data.

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