The use of sugar-cane waste (Bagasse) energy as substitution of fossil-fuel energy in Krebet Sugar Factory, East Java, Indonesia

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Abstract. Industry is one form of economic activities that process raw material and/or utilize industry resource to produce product with a higher value or benefits. Rapid growth of industrial activities an increase community’s welfare. While on other side, industrial development can increase the value of CO2 emission that can influence global warming. Krebet Sugar Factory in one of the largest sugar industries in Indonesia and so far, still using fossil fuels (gasoline, diesel, residue oil) as energy resource in production process. Based on 2011 National Greenhouse Gas Emission Reduction Action Plan, CO2 emission reduction’s target in Indonesia, especially in industrial sector for year 2020 is 0,001 Gton CO2 (Scenario 26%). One of mitigation action that can be done to support CO2 emission reduction is using alternative energy resource/ fuel bagasse. The aim of this research is to evaluate utilization of factory waste for alternative energy resource/fuel (bagasse). Krebet Sugar Factory have production capacity of 840 ton/day. Average of Electricity resource provided by PT. PLN is 26,40 KVA/month, while the electricity average usage provided by Krebet Sugar Factory’s power plant is 4,320 KVA/month and Krebet Sugar Factory Fuel’s consumption for one year is 19,500 ton. Based on production data, average bagasse production of Krebet Sugar Factory is 420.533,34 ton so can produce energy value in the amount of 4.878,19 Terajoule that can be used as an alternative energy resource.

1. Introduction
Krebet Sugar Factory in Malang, which having been operating since 1906 is one of the largest sugar companies in Indonesia, it is located in Bululawang District, Malang Regency. In 2004, Krebet SF produced 6000 tons of sugar per day and in 2010, it increased to 11,500 tons of sugar per day and this factory will continue to increase its production capacity. Greenhouse gases in sugar factory come from process of production, combustion, utilization of electrical energy, and waste of production [1].

The use of large-scale energy at sugar factory can increase greenhouse gases (CO2) production that affect global warming. According to [2], the main gases which are categorized as greenhouse gases and which have the potential to cause global warming are carbon gases (CO2), CH4, and NO2. [3] states that carbon gases, especially CO2, have percentage of 50% in total greenhouse gases.

In accordance to National Greenhouse Gas Emission Reduction Action Plan 2011, Indonesia's GHG emission reduction target by 2020 is 26% by using mitigation actions which one of them is by the development of carbon sequestration. According to [4], one effort to reduce greenhouse gases is by replacing fossil fuels and utilizing industrial waste as a source of alternative energy. Data of previous
research show the use of fossil energy sources in Krebet SF is 19,550 tons/year (gasoline, diesel and residual oil). From the use of fossil fuels in this case produce CO2 emissions of 61,568.04 tons.

2. Literature review

2.1. Sugar Production Process

The sugar factory industrial activity basically has 6 stages: milling station, refinery station, evaporation station, crystallization station, separation station, and settlement station [5].

- **Milling Station**: The process at milling Station can be divided into two stages; they are preliminary process and sugar cane extraction.

- **Purification Station**: The non-sugar substances which are also contained in sugar nira are separated by controlling the temperature, pH, and remaining time in each equipment, so sucrose which is contained in sugar nira is not inverted. Most of non-sugar substances will be separated, one is called as blotong and the result of this nira is called pure/clear nira.

- **Evaporation Station**: Pure/clear nira still has high content of water. To make the use of steam in process of crystallization efficient, water clear nira is evaporated until it reaches 30 - 32 degrees Celsius. The evaporation process is carried out vacuum.

- **Crystal Station**: Thick nira is further evaporated until sugar crystals forms. This crystallization process is also carried out under vacuum. To achieve the desired crystal size, process of cooking is done in various stages. Final result of the Crystal Station is massecuite; sugar crust which surrounding still contains strup layers.

- **Separation Station**: Sugar crust in massecuite is separated from its strup by utilizing centrifugal force. This centrifugation process is also performed in several stages, depending on the type of massecuite that is being rotated.

- **Completion Station**: Sugar which is produced in Rotation Station still contains high content moisture, therefore sugar is dried and cooled using Sugar Drier and Cooler (SDC) to obtain sugar with desired water content and temperature.

2.2. Sugar Factory’s CO2 Emission Source

Sugar factory industries that using fossil and biomass fuels potentially produce GHG (Green House Gas) emission and contributing global warming. Based on [1], The source of CO2 Emission in Sugar factory comes from burning fuel and solid waste processing. CO2 emission sources based on Research and Development center of Environment and Forestry Ministry of Indonesia (2017) are Industrial process and Product Usage, Energy Consumption and Industrial Waste.

Based on [6], CO2’s measurement result in the process in milling station is higher that CO2 measurement result in other stations. According to President’s Regulation Number 61/2011 in National Action Planning for GHG Emission Reduction, Sugar Factory is classified in Food and Beverages Industry that has a GHG Emission Reduction’s target amount 0.069 Mton CO2 in year 2020.

3. Methods

The variables used in this research are Bagasse Production from Sugar Production Process, Energy Consumption of Bagasse, Energy’s Conversion Factor of Bagasse and Co2 Emission Factor of Bagasse. Research method using alternative scenario technique based on existing data. Alternative scenario performed through CO2 emission production from bagasse usage. Calculation of CO2 using CO2 emission conversion which has been recognized by [2].

\[
GRK_{\text{emission}} = \text{fuelconsumption} \times f_{\text{emissionfactor}}
\]

To identify energy consumption of bagasse is to multiply the amount of bagasse production with the calorie value of bagasse. Based on ICSEFA (2014), the calorie value of bagasse is 1,852 kcal/k or 11,667kJ/Gg.
Energy consumption of bagasse = bagasse production x 11.6 TJ/Gg \hspace{1cm} (2)

Afterwards to identify CO2 emission production from bagasse usage is to multiply energy value of bagasse with CO2 emission factor. Bagasse is classified as biomass energy, so the CO2 emission factor used in this research is 100,000-ton CO2/TJ.

**Bagasse CO2 Emission = Energy consumption of bagasse x 100,000 CO2/TJ** \hspace{1cm} (3)

Emission factors are obtained from emission factors that have been determined by IPCC *(the default)*. Fuel consumption used by the Krebet sugar factory is Gasoline, Solar and Residue in Ton/Year units. The third factor in emissions from these fuels can be seen in Table 1.

| No | Product  | CO2 Emission Factor (Ton/TJ) |
|----|----------|-------------------------------|
| 1  | Gasoline | 68,6                          |
| 2  | Solar    | 73,4                          |
| 3  | Residue oil | 76,6                          |

Source: IPCC, 2006

4. Results

Krebet Sugar Factory is a sugar factory owned by PT. The Rajawali I Sugar Factory which is located in Krebet Village, Bululawang District, Malang Regency. This location is same as the location of Krebet Sugar Factory II. Area used by Krebet SF is an area of 24.08 hectares. Production activities in Krebet SF are a neutral sulfitation process which is done physically and chemically, with production capacity of 70,000 tons of cane per day. The process of activities that happen in sugar production are as follows.

1. Production activities

   Stages of sugar production ranging from sugar cane at Krebet sugar factory are as follows.

   ![Sugar Production Process](image)

   **Figure-1. Sugar Production Process**

2. Post-production activities

   Post-production activities are period of sugar cane planting, so that the process of sugar production is stopped until harvest time of sugar cane. Activity that occurs during the post-production season is only the mobilization of labor and office activities, so that the only energy source used is electricity.
4.1. Sugar Factory Production Capacity
Sugar production capacity in Krebet Sugar Factory on planting season year 2010-2014 which average is 1,501,904.78 tons of sugar cane with average sugar result of 105,071,742 tons/year. The final product consists of two types, they are sugar and drops.

| Plant season | Rendemen (%) | Production (ton) |
|--------------|--------------|-----------------|
|              | Sugar Cane   | Sugar           |
| 2011         | 7.2          | 1,051,286,9     | 75,377,27     |
| 2012         | 6.5          | 1,583,997,8     | 103,118,26    |
| 2013         | 6.8          | 1,394,934       | 94,855,51     |
| 2014         | 6.7          | 1,715,724,8     | 114,095,77    |
| 2015         | 7.8          | 1,763,580,4     | 137,911,9     |
| Average      |              | 1,501,904,78    | 105,071,742   |

4.2. Energy Consumption
Electrical energy used in the Krebet SF operation and activities of lighting is supplied by PT. PLN and electricity coming from power plants owned by Krebet SF. The use of electricity that is supplied by PT. PLN is averagely 26.40 KVA per month, while electricity usage comes from Krebet SF power plants is averagely 4,320 KVA per month.

Operational activities and sugar production in Krebet sugar factory use fossil fuel energy which includes gasoline, diesel fuel, residual fuel and lubricants. The following table shows consumption of fossil fuel usage in Krebet sugar factory per year.

| Fuel Type   | Use (Ton/tahun) |
|-------------|-----------------|
| Gasoline    | 1.500           |
| Diesel      | 5.000           |
| Residue     | 10.000          |
| Oil         | 3.000           |
| Total       | 19.500          |

Based on Table 3, known that fuel consumptions by Krebet sugar factory are gasoline, diesel fuel, residual fuel, and lubricating oil. Total use of Krebet sugar factory fuel in one year is 19,500 tons of fuel.

4.3. Krebet Sugar Factory’s Solid Waste
Solid waste which is generated from the sugar production process consists of bagasse, blotong, and kettle ash. Bagasse comes from residue of milled sugar cane which sap milked at the milling station. Blotong is result of separation of sap and its manure by filtration at purification station. Kettle ash comes from the residue of combustion on the boiler.

4.4. CO2 Emission of Fossil Energy Resources
The total fuel used in Krebet sugar factory is 19.5 Gg/Year, the largest use is residual oil which is 10 Gg/year.
Energy consumption of Krebet sugar factory in one year is 818.8 Terajoule/year. Then it is calculated with CO2 emissions from fuel energy which amount is shown in Table 5.

| Fuel      | Energy (TJ) | Emission Factor (Ton CO2/TJ) | Emission Factor (Gg CO2) | CO2 Emission (Ton CO2) |
|-----------|-------------|------------------------------|--------------------------|------------------------|
| Gasoline  | 69.6        | 69.300                       | 4.82                     | 4.823,28               |
| Diesel    | 215         | 74.100                       | 15.93                    | 15.931,5               |
| Residu    | 404         | 77.400                       | 31.27                    | 31.269,6               |
| Oil       | 130,2       | 73.300                       | 9.54                     | 9.543,66               |
| Total     |             |                              |                          | 61,568,04              |

Based on Table 5, and based on the amount of fuel energy, it is known that CO2 emissions produced by the Krebet sugar factory are 61.568 Gg CO2 per year or 61,568.04 Ton CO2 per year (1 Giga gram = 1000 Ton)

4.5. Use of Sugar Cane Waste (Bagasse)

One way to reduce CO2 emissions is by using bagasse as an alternative fuel to supply energy of Krebet sugar factory. Krebet sugar factory itself produces waste of bagasse. Therefore, the purpose of bagasse which is used as alternative fuel is to apply zero waste, thus there is still leftover bagasse which can be used as raw material for particle board production.

Sugar cane waste (Bagasse) is a side-product in sugar-making process, especially from grinding process (Ministry of Environment, 2005). Bagasse contains mostly lingo-cellulose, 48-52% water, 47.7% fibre. Other elements contained in bagasse are 47% carbon, 6.5% hydrogen, 44% oxygen, and 2.5% ash. It is known that bagasse production is averagely of 280 kg production or 28% per 1 ton of sugarcane (Rabelo, 2011). According to review ministry of environment, calorific value of 1 ton dry bagasse is equivalent to 598 liters of diesel. The following is bagasse production in Krebet Sugar Factory.

| Year | 1 Year Production (ton) |
|------|-------------------------|
|      | Sugar Cane | Sugar | Bagasse |
| a    | b           | c     | d = b x 28% |
| 2011 | 1.051,286,9 | 75.377,27 | 294.360,33 |
| 2012 | 1.583,997,8 | 103.118,26 | 443.519,38 |
| 2013 | 1.394,934  | 94.855,51  | 390.581,52  |
| 2014 | 1.715,724,8 | 114.095,77 | 480.402,94  |
| 2015 | 1.763,580,4 | 137.911,9  | 493.802,51  |
| Σ    | 1.501,904,78 | 105.071,742 | 420.533,34  |

Assuming that 280 kg or 28% of 1 ton of sugar cane becomes bagasse, the average bagasse production from 2011 to 2015 is 420,533,34 ton. Average value of bagasse production will be used to determine average energy value that can be removed from the bagasse. Conversion calculation of bagasse production into energy uses the IPCC formula, 2006. The following is a calculation of bagasse energy conversion.
Table 7. Total Energy of Bagasse

| Average Bagasse Production (Ton) | Average Bagasse Production (Gg) | Calorie value (TJ/Gg) | Energy (TJ) |
|---------------------------------|---------------------------------|-----------------------|-------------|
| A                               | b = a / 1000                    | c                     | d = b x c   |
| 420.533,34                      | 420,53                          | 11,6                  | 4,878,19    |

If it is compared to other energy sources in Krebet SF, Bagasse has greater energy value compared to any fossil energy sources.

Table 8. Energy Resources Comparison in a year

| Energy Resources | Energy (TJ) |
|------------------|-------------|
| Gasoline         | 69,6        |
| Solar            | 215         |
| Residue oil      | 404         |
| Lubricant        | 130,2       |
| Bagasse          | 4,878,19    |

Large energy value will result in large CO2 emissions and so does bagasse energy, it has large emission factor which is equal to other biomass fuel emission factor (100,000 tons CO2 / TJ), so this recommendation is done by simulating bagasse energy usage in order to find out that energy is adequate to replace fossil fuels and that it has lower CO2 emission than energy from fossil fuel. Based on the simulation that has been done, there are amount of CO2 emission output. The following is comparison of CO2 emissions results in existing conditions at the time of bagasse usage.

![Figure-2. CO2 Emission Comparison Between Existing and Bagasse Usage](image)

In graphic above, it is known that point tangent of x and y (10.7; 61,57) with curve equation is $y = 5,8773 + 520,19x$. From curve equation y, it is known that intersection point between line x and y lies at 5.8773 if x = 0. If bagasse energy values of 0, then value of carbon emission equal to 5.8773. Intercept (5,8773) can also be interpreted as the influence of variables or other factors outside this study that is not researched. Energy value that can be allowed to be used in as substitution of fossil fuel energy based on curve equation $y = 5,8773 + 520,19x$ is maximum of 10.7% from total bagasse energy which produced. Thus, simulation that is used for the recommendation is use of bagasse energy by 10%, since energy value is close to the value of fossil fuel energy which used in Krebet sugar factory and it has lower CO2 emissions value than the existing value of CO2 emissions. The following is energy calculation which uses 10% of bagasse production.
Table 9. Energy Resources Comparison in a year

| Average Bagasse Production (Gg/year) | 10% of a (Gg/year) | Calorie Value (TJ/Gg) | Energy (TJ) |
|-------------------------------------|--------------------|----------------------|-------------|
| a                                   | b = a / 10%        | c                    | d = b x c   |
| 420.53                             | 42.05              | 11.6                 | 487.82      |

From the calculation of energy which is generated by bagasse, it is known total CO2 Emission can be generated through the following calculations.

Table 10. CO2 Emission of Baggasse

| Bagasse Production (Gg/year) | Energy (TJ) | CO2 Emission Factor (Ton/TJ) | CO2 Emission (Gg) |
|------------------------------|-------------|------------------------------|-------------------|
| a                            | B           | C                            | d = b x (c/10^6)  |
| 42.05                        | 487.82      | 100.000                      | 48.78             |

Based on Table 9 and Table 10, it can be seen that value of the energy produced from 487.82 Gg bagasse is amounts to 42.05 Terra Joule. Then it will be calculated along with CO2 emissions from the energy released by bagasse, which generating CO2 emissions of 48.78 Gg CO2. The following is comparison of each existing CO2 emission values with the value of CO2 emissions during its use.

Table 11. CO2 Emission Comparison

| Comparation        | Existing | Simulation |
|--------------------|----------|------------|
| Gasoline           | 4.82     | -          |
| Diesel             | 15.93    | -          |
| Residue            | 31.27    | -          |
| Oil                | 9.54     | 9.54       |
| Bagasse (10%)      | -        | 48.78      |
| Total (Gg/Year)    | 61.57    | 58.32      |
| Deviation          | 3.25     | -          |

Based table 11, it can be seen that there are differences in results of existing CO2 emissions during and after the simulation. On simulation, it can reduce CO2 emissions about 3.25 Gg / year or about 5.3% of total CO2 emissions from the use of existing fossil fuels.

5. Conclusion

Bagasse is one of Sugar Factory’s solid waste comes from residue of milled sugar cane which sap milked at the milling station and has average production amount 420.533,34 ton/year of bagasse. For sugar production, Krebet Sugar Factory consumed 19,500 tons of fuel per year that content 818,8 TJ/year of energy and produce 61.568 Gg of CO2 per year or 61,568.04 Ton of CO2 per year (1 Giga gram = 1000 Ton).

One way to reduce CO2 emissions is by using bagasse as an alternative fuel to supply energy of Krebet sugar factory. Every year Krebet Sugar Factory produce 420.533,34 ton/year of bagasse that content 4.878,17 Terra Joule of energy. Based on the comparison of bagasse energy and conventional energy that has been used, it can be concluded that Bagasse is very potential for alternative energy in Sugar Factory. Bagasse also produce CO2 and by calculating CO2 emissions produce by bagasse, it can be concluded that the use of 10% bagasse can reduce the amount of CO2 emissions from Krebet Sugar Factory.
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References
[1] Sihombing S R A BR 2012 Potensi Penurunan Emisi Gas Rumah Kaca Pada Industri Gula (Studi Kasus PT PG RAJAWALI II Unit PG SUBANG) Skripsi (Bogor: Teknologi Industri Pertanian IPB)
[2] IPCC 2006 IPCC Guidelines for National Greenhouse Gas Inventories Energy; Chapter 2: Stationary Combustion 2 (Washington D.C: USA)
[3] Rukaesih A 2004 Kimia Lingkungan (Yogyakarta: Andi)
[4] Fiantisca A 2002 Kajian Inventarisasi Gas Rumah Kaca Pada Sektor Pertanian dan Kehutanan dengan Menggunakan Metode IPCC Skripsi (Bogor: Jurusan Geofisika dan Meteorologi-FMIPA, IPB)
[5] Santoso B 2005 Proses Pembuatan Gula dari Tebu Pada PG X (Jakarta: Universitas Gunadarma)
[6] Purwaningsih E 2011 Polusi Udara dan Pengaruhnya terhadap kesehatan Masyarakat (Studi Kasus Fabrik Gula Mojo Sragen) Tesis (Yogyakarta: Universitas Gajah Mada)
[7] Peraturan Mentry Perindustrian 2011 Peraturan Mentry Perindutrian Nomor 64/M-IND/PER/7/2011 tentang Jenis-Jenis Industri dalam Pembinaan Direktorat Jendral dan Badan di Lingkungan Kementrian Perindustrian